Sewage Works

THE PORTLAND SEWAGE WORKS PROJECT *

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The Willamette River divides the city of Portland into two areas as shown in Figure 1. The west side contains the main business section and the west-hills residential area, being approximately one-third of the total area of the city of 67 square miles. The northern boundary of the city is about 2½ miles from the confluence of the Willamette and Columbia Rivers. Multnomah Channel is at the northern boundary of the city and is important in that at low flows a large proportion of the flow in the Willamette passes to the Columbia River via this channel. The minimum flow of the Willamette River is a little less than 4,000 c.f.s., while that of the Columbia River is to be regulated at about 75,000 c.f.s.

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Pollution of Willamette River

That the Willamette River reaches Portland in a highly polluted condition

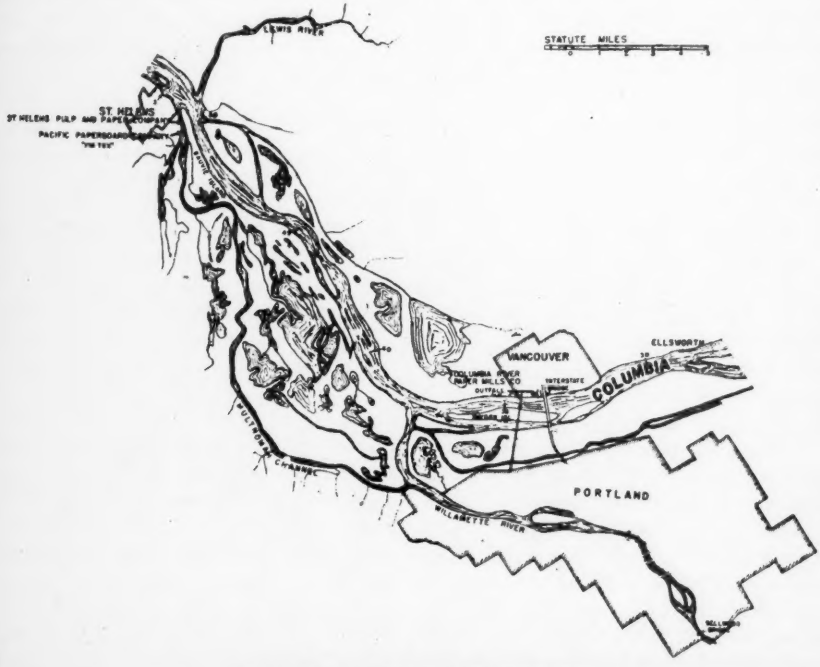

FIGURE 1.—Portland and vicinity.

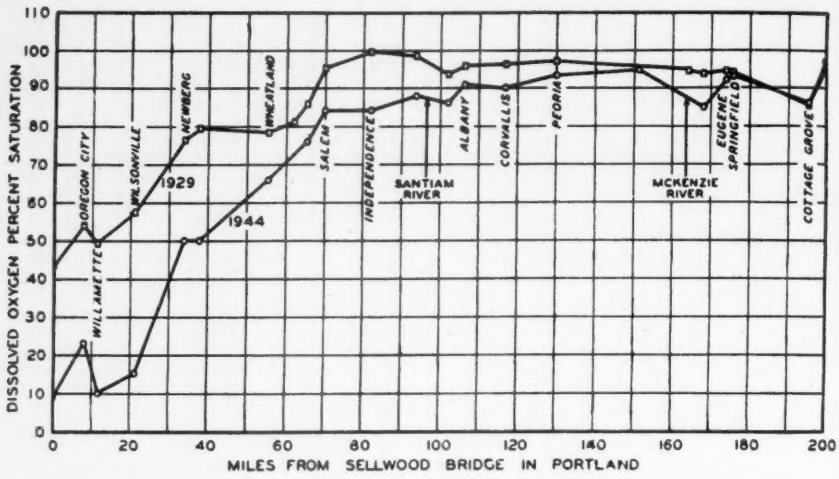

FIGURE 2.—Per cent saturation of dissolved oxygen in the Willamette River above Sellwood Bridge.

has been recognized for a long time but it was not until 1929 that the extent of the pollution was known. A sanitary survey was conducted by the Oregon State College Experiment Station during July and August of that year and reported in "A Sanitary Survey of the Willamette Valley" (1). This survey indicated that the saturation of dissolved oxygen in the waters of Willamette River was about 42 per cent at Sellwood Bridge at the extreme southern part of the city.

Again in 1944 a sanitary survey was made of the Willamette River from above Cottage Grove to Sellwood Bridge. The results of this survey were published in "1945 Progress Report on Pollution of Oregon Streams" by the same institution (2). Figure 2, taken from this latter report, shows the dissolved oxygen in per cent saturation in the stream from the Sellwood Bridge to above Cottage Grove. The stream had deteriorated since 1929 until its saturation of dissolved oxygen was reduced to 10 per cent. This is before any of the sewage from Portland is discharged into the Willamette River for disposal.

Because of lack of information concerning the condition of the Willamette River within the city boundaries, and as such data were needed, the city authorized G. W. Gleeson of Oregon State College to conduct a sanitary survey of the river from the Sellwood Bridge to Columbia River. This survey was conducted during September, 1934, and reported in "A Sanitary Survey of the Willamette River from Sellwood Bridge to the Columbia River" (3). Figure 3, taken from this report, shows the cross section of the river at Sellwood Bridge and the results of a dissolved oxygen traverse. This indicated that little difference in the dissolved oxygen content existed across the stream. The saturation was about 32 per cent, which was a reduction of approximately 25 per cent from the 1929 value at the same location but considerably higher than the 1944 value at this point. The stream has deteriorated steadily since the results of the first survey were made known.

The variation and average dissolved oxygen content of the stream at the seven regular sampling stations used by Mr. Gleeson are shown in Figure 4,

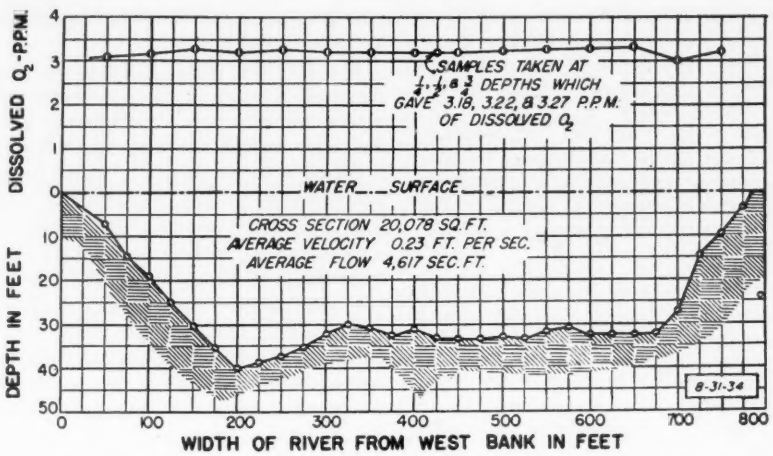
DISSOLVED O2-P.P.M.
DEPTH IN FEET
SAMPLES TAKEN AT 1/4, 1/2 & 3/4 DEPTHS WHICH GAVE 3.18, 3.22, & 3.27 P.P.M. OF DISSOLVED O2
WATER SURFACE
CROSS SECTION 20,078 SQ. FT.
AVERAGE VELOCITY 0.23 FT. PER SEC.
AVERAGE FLOW 4,617 SEC. FT.
8-31-34
WIDTH OF RIVER FROM WEST BANK IN FEET

FIGURE 3.—Dissolved oxygen traverse at Sellwood Bridge.

which has been taken from his report. Station 3 at Burnside Bridge is about in the heart of the city and some of the larger sewers empty into the river just above and below this station. The effect of this sewage upon the dissolved oxygen of the stream is readily apparent and a stretch of depleted water existed for approximately 15,000 feet. In regard to the variation of the dissolved oxygen at different depths this report states:

"It will be noted that the variation in dissolved oxygen content at all depths of sampling at the various stations is the same within experimental error for all of the stations above the Spokane, Portland & Seattle Railway Bridge. This condition is

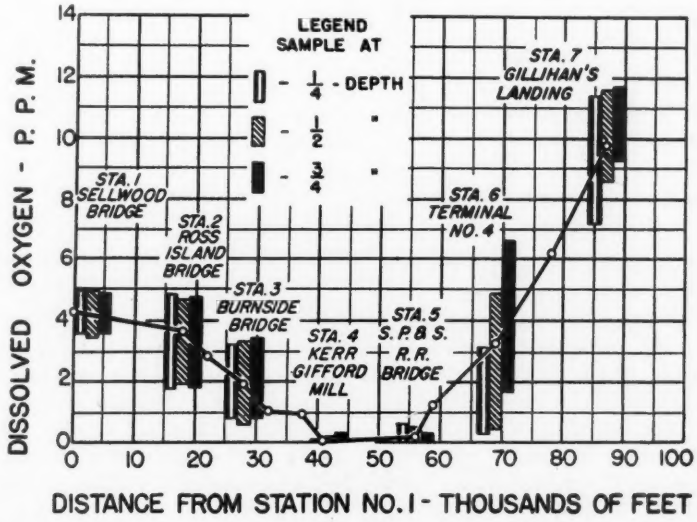
DISSOLVED OXYGEN - P. P. M.
LEGEND
SAMPLE AT
1/4 - DEPTH
1/2
3/4
STA. 1 SELLWOOD BRIDGE
STA. 2 ROSS ISLAND BRIDGE
STA. 3 BURNSIDE BRIDGE
STA. 4 KERR GIFFORD MILL
STA. 5 S. P. & S. R. R. BRIDGE
STA. 6 TERMINAL NO. 4
STA. 7 GILLIHAN'S LANDING
DISTANCE FROM STATION NO. 1 - THOUSANDS OF FEET

FIGURE 4.—Variation and average dissolved oxygen at the regular sampling stations on Willamette River within the city.

not true of the stations down the river. The variations encountered are of different magnitude and the mean values indicate an increasing dissolved oxygen content from top to bottom of the river. This variation is due to the fact that, especially at high tide but in a measure at all tides, the Columbia River water has backed into the Willamette channel on the bottom and increased the dissolved oxygen concentration."

The waters of the Columbia River are colder than the Willamette River waters and are practically saturated with oxygen, which explains the above condition.

A study of the currents and rates of flow at the seven sampling stations indicated that, during low stages of the river, it takes about 7.6 days for the waters of the Willamette to pass from Sellwood Bridge to Multnomah Channel. Actually, during high tide and with the river at a low stage, one can observe floating material going upstream. This condition does not permit the organic material to reach quickly the waters of the Columbia with their high oxygen content.

The period of oxygen depletion is coincident in time with the low-water stage. This period in all probability never exceeds three months. However, except during flood, the oxygen content of the stream is affected adversely at all times of the year.

Financial Program and Engineering Studies

The growing need of abating the pollution of the Willamette River has been a subject of discussion for many years. As long as 25 years ago the late C. H. Smith, while Sewer Engineer for the city, had worked out a preliminary plan for the collection and treatment of the sewage of Portland. However, it was not until the depression years that a group of unemployed prevailed upon the City Council to authorize the preparation of plans, specifications, and estimates for a sewage collection and treatment system.

Based upon hastily prepared and incomplete plans (calling for treatment at six plants) a self-liquidating bond issue of $6,000,000 was approved by a 2 to 1 vote on July 21, 1933. Legal interpretation of the authority thus granted the city confined the proposed construction to that conceived by those who prepared the incomplete plans. An application was submitted to the PWA for a loan of $6,000,000 and a grant of $2,000,000. This was rejected as the plans submitted were not sufficiently complete to judge the merits of the application.

Following this, the people of Portland rejected a proposal by which the self-liquidating bonds would be supported out of general tax funds. Due to the legal difficulties and the fact that the original plans were not practical the self-liquidating bonds were never sold.

Just prior to the election of July 21, 1933, the City Council employed a board of consulting engineers consisting of Messrs. Koon, Cunningham, and Dieck to make a preliminary report on the collection and treatment of sewage for Portland. In the fall of the same year, the late Harrison P. Eddy was retained as consultant. His report was submitted in October, 1933, and carried the recommendation:

". . . that a system of intercepting sewers and necessary pumping stations be built to carry the sewage to North Portland Harbor into which it will be disposed after suitable treatment if any be required."

This was in line with the Smith Plan and the recommendations of Koon, Cunningham, and Dieck. (North Portland Harbor is called Oregon Slough; it is a part of the Columbia and carries a considerable portion of the flow of the river.)

A charter amendment was approved by the people in 1938 granting the

City Council authority to construct and operate a sewage collection and treatment system, and authorizing a levy for a sewer service charge not to exceed one-third of the charges for water, for the purpose of providing funds to finance the cost of the system. Since August, 1940, the city has been collecting a service charge which is about 40 per cent of that authorized by this charter. This service charge is based on water use; quarterly payments vary between 25 and 70 cents per residence. Collections from this source amounted to $1,246,786 to December 31, 1946.

The city convened a board of consulting engineers in 1939 consisting of Abel Wolman, Wellington Donaldson, Carl Green, and R. H. Corey. This board submitted its report on August 19 of that year. The board made the following recommendation:

". . . that the sewage discharge from all the outlets on the Willamette River and Columbia Slough from the City of Portland and its immediate environs be collected and transported to a site in the vicinity of Columbia Slough, there to be treated by sedimentation and then discharged into the Columbia River through multiple outlets."

Based upon this report general obligation bonds in the amount of $12,000,000 were authorized by the

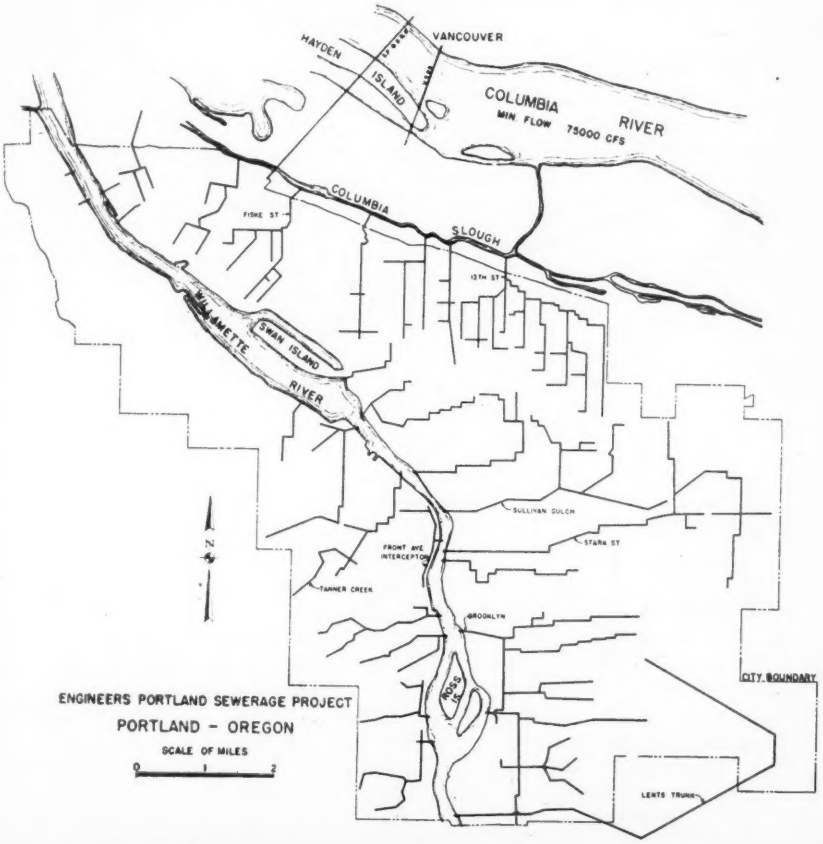

FIGURE 5.—Some of the more important sewers of Portland.

voters in May, 1944. The ordinance granting the city the authority to sell the bonds is sufficiently broad to permit freedom of design by the engineers, yet it requires the carrying out of the general recommendations of the "Wolman Report." The city has sold these bonds and invested the proceeds in Government securities, the investment return on which is slightly greater than the interest charge on the bonds.

The fund accumulating through sewer service charges has provided the funds required to pay for special investigations carried on by the City Engineer's office, engineering fees, and the purchase of the treatment plant site.

In February, 1944, the city authorized the firms of Stevens & Koon and John W. Cunningham & Associates to prepare the designs for an intercepting sewer system and a sewage treatment plant. This work has been carried on as a joint venture under the name of "Engineers Portland Sewerage Project." An engineering board consisting of the City Engineer and a member from each of the participating firms has directed the work, with A. M. Rawn, Chief Engineer, Los Angeles County Sanitation Districts acting as a special consultant. The design of the project is nearing completion.

Sewers of Portland

The sewers of Portland, 61 in number, are of the combined type. Fifty

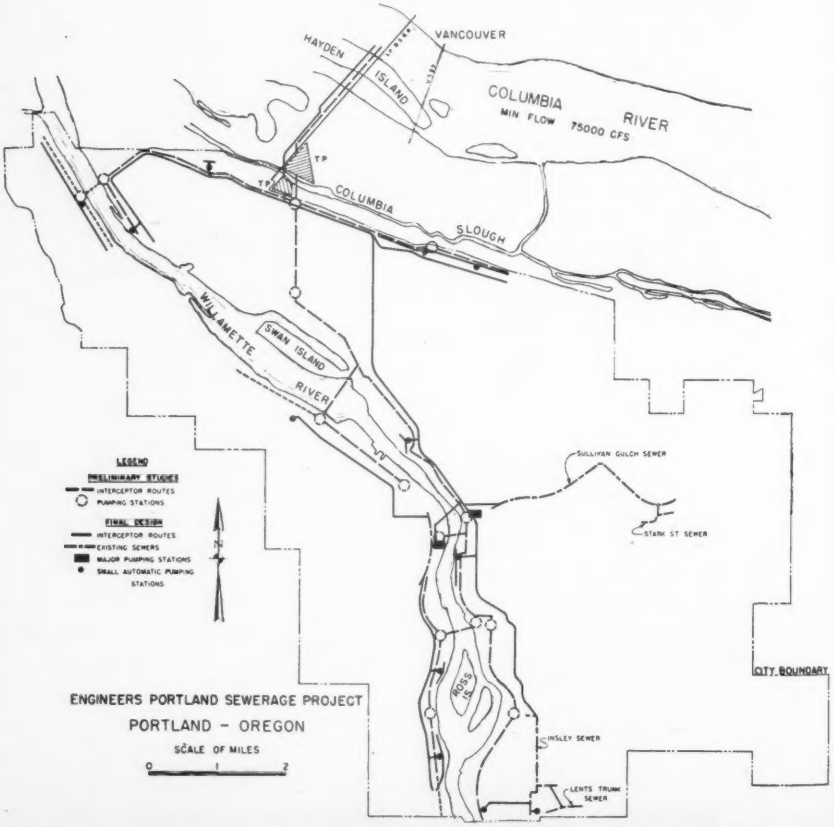

FIGURE 6.—Preliminary or "low level" interceptor route and the "high level" location.

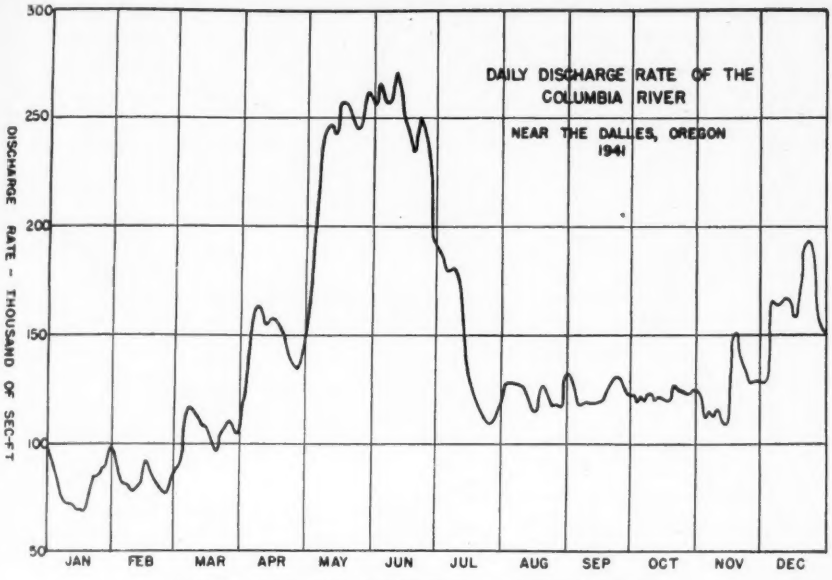

FIGURE 7.—Typical discharge of the Columbia River.

of these discharge directly into the Willamette River and eleven into Columbia Slough; their sizes range up to 10 ft. in diameter. Figure 5 illustrates some of the more important sewers, and in a general way indicates the natural drainage of the area. As would be expected the point of discharge of most of the sewers is below or near low water level in the river.

Interception Studies

After a study of the sewer system the logical solution to the interception of the sanitary sewage seemed to be the construction of intercepting sewers paralleling the river at a low level. Where the depth of the interceptor became excessive a pumping station could be built to lift the sewage and again flow would be by gravity until it became necessary to lift the sewage again. Such a scheme was visioned by those who had considered the problem. However, local engineers considered the possibility of high level interceptors, as did the "Wolman Board," which stated in its report:

"It still remains to be demonstrated, for example, whether all of the sewage should be collected by low level interceptors, by high level interceptors, or by combinations thereof. . . . Preliminary studies which the Board has undertaken since its arrival in Portland and similar studies by engineers concerned with the problem made prior to our arrival, give support to the hope that a combination of high level gravity and low level pumping interceptors will yield the greatest economy for the future."

The low level intercepting system is indicated in Figure 6 and is shown by dashed lines. Numerous problems became apparent from the beginning. The location of the interceptor below river level introduced problems in the design and operation of diversion devices. To intercept low rates of flow and permit the higher storm rates to flow down the sewer is not too difficult. There is a complication introduced by backwater from the river into the sewer, however, with and without storm water runoff. During May, June, and July the Columbia River is in flood (Figure 7) and water is backed

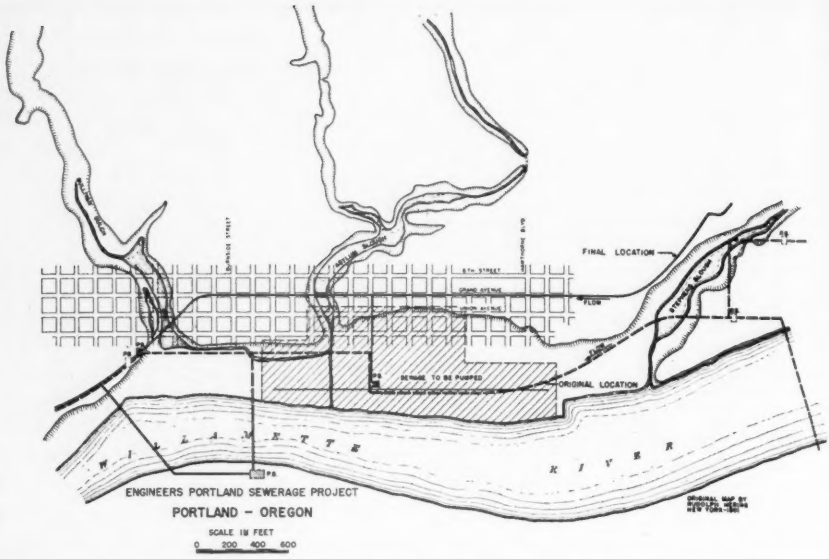
FINAL LOCATION
ORIGINAL LOCATION
SEWAGE TO BE PUMPED
W I L L A M E T T E R I V E R
ENGINEERS PORTLAND SEWERAGE PROJECT
PORTLAND - OREGON
SCALE IN FEET
0 200 400 600

FIGURE 8.—Original and final location of the interceptor on the east side in the heart of the city.

up in the channel of the Willamette River. Floods on the Willamette River occur mostly in winter. These conditions would not permit runoff from storms passing beyond the diversion devices without first flooding the interceptor.

Also, the low level interceptors as proposed were to pass under the sewers near the river, which required construction below river level. The interceptors would have had to be built through unstable ground consisting of old, filled sloughs. These original sloughs and adjacent low grounds were filled with sawdust, slabwood, brickbats, and miscellaneous debris, making the route anything but desirable for the location of large and deep sewers.

Figure 8, which was prepared from an old drawing made by Rudolph Hering in 1891 when he designed a comprehensive sewer system for East Portland, illustrates the extent of the sloughs and low ground that once existed in the heart of the east side. At one time Union Avenue was supported by pile trestles for a portion of its length. The low level intercepting system required the route to traverse a great part of the various sloughs along the river on both sides. A study of old maps and information gained from responsible older residents definitely indicated that difficult construction would be encountered if the low level interceptors were to be built.

Fortunately, most of the sewers of Portland have fair grades near their points of discharge, and the points of diversion generally did not have to be placed an unreasonable distance from the river. Only for the Sullivans Gulch sewer was it necessary to locate the diversion at a considerable distance from the river, and that was to save the pumping of the sewage. This diversion sewer is mostly in tunnel and is approximately 3,000 ft. long. The maximum sanitary flow to be intercepted by this one diversion is estimated to be 12.7 m.g.d., including 5.2

m.g.d. previously intercepted from the Stark Street sewer.

The scheme of high level interception is shown in Figure 6 along with the low level routes. The interception of the sewage at the higher level permitted almost all of the sewage originating north of Sullivans Gulch to reach the Columbia River by gravity. The sewage from the west side and that originating south of Sullivans Gulch must be pumped. The estimated maximum volume of sewage to be pumped is 118 m.g.d., of which only 7.2 m.g.d. will be pumped twice. The remainder, or 57 m.g.d., will flow by gravity to the Columbia River. The areas from which the sewage will flow by gravity and from which it must be pumped are shown in Figure 9.

Due to the high level interception it has been necessary to provide small intercepting sewers and pumping stations to lift the sewage in a few minor areas to the main interceptor. In some cases it has been necessary to design new sanitary sewers (or storm sewers if such seemed more feasible) to separate the sewage. In all cases, however, the pumping stations are expected to handle relatively small quantities of sewage, and the stations have been designed to operate as fully automatic as possible so that an attendant will not be necessary except for routine visits.

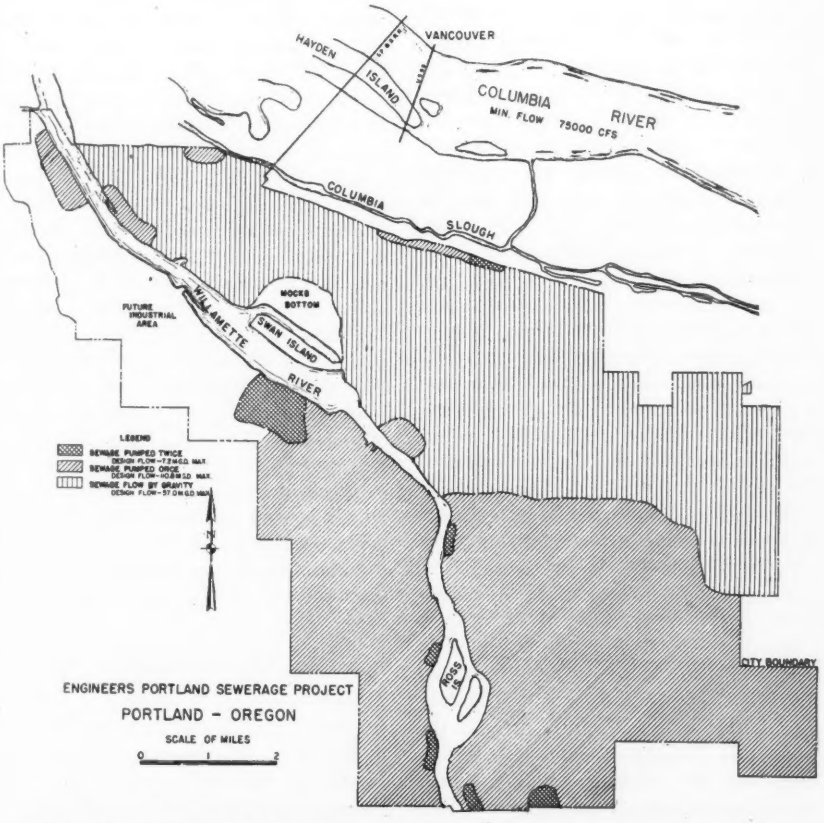

FIGURE 9.—Map of city showing areas from which the sewage will flow to the Columbia River by gravity and by pumping.

Use of Existing Sewers

Existing sewers have been used to advantage. The routes of the Stark Street and Sullivans Gulch sewers approach each other near 50th Street and, since the former at this point is sufficiently higher than the other, a gravity diversion has been planned to intercept 5.2 m.g.d. This flow will pass to the Columbia River by gravity via the Sullivans Gulch sewer and through a diversion to the main interceptor.

The sewage (estimated at 3.5 m.g.d.) originating below the diversion point on the Stark Street sewer is to be intercepted by the main interceptor and pumped at the Sullivans Gulch pumping station. In the south part of the city the sanitary sewage from the Lents trunk sewer is to be diverted by gravity to the Insley sewer through which it will flow for over a mile before the sewage is picked up at the diversion for the Insley sewer. Also, two small pumping stations are planned to have their discharge transported by the same Insley sewer.

The large Front Avenue intercepting sewer, constructed to carry primarily storm flow to the Ankeny Street pumping station, is to be used to concentrate all of the west side sewage at the same pumping station, from which it will be pumped to the main interceptor on the east side of the river. All of the existing sewers utilized in this manner are fairly large and will not be overloaded except possibly during heavy storms.

Willamette River Siphon

Two of the originally proposed inverted siphons under Willamette River have been eliminated by concentrating all of the sewage originating on the west side (except from the Linnton area) at the existing Ankeny Street pumping station. From here the sewage is to be pumped through an inverted siphon to the main interceptor on the east side. It then will flow by gravity to Columbia River.

Two cast-iron pipes, 30 and 42 inches in diameter, will form the siphon. These will have mechanical joints and are to be laid in a trench in the bottom of the river with approximately 10 ft. of cover. The Willamette River is quite deep and at this point the two lines must be placed 65 ft. below low water.

Ankeny Street Pumping Station

There are five pumps in the existing Ankeny Street Station: three 30,000-g.p.m. and two 10,000-g.p.m. units. The three large pumps are of the single vane type and the two smaller units are 18-in. non-clog pumps. They operate against a total dynamic head range from zero to about 20 feet. One of the 30,000-g.p.m. units is to be removed and two smaller vertical pumps installed in its place.

Each unit is to be driven by a double synchronous motor providing two operating speeds. The smaller unit is to be a non-clog and will pump 7.5 and 15 m.g.d. depending upon the speed at which it is to be operated. The larger unit is to be a mixed flow pump and will have operating capacities of either 20 or 35 m.g.d. Thus the total capacity of the station will be increased. However, these new units will normally pump to the east side interceptor while the remaining pumps will be used as heretofore to pump storm water to the river. The total dynamic head range against which the new units are to operate is from 45 to 56 feet.

Outfall Siphons

Two inverted siphons are required for the outfall sewer: one shallow siphon is to be constructed under Columbia Slough and a deeper one under Oregon Slough. The former will be 15 ft. below low water while the other must be 40 feet. These requirements

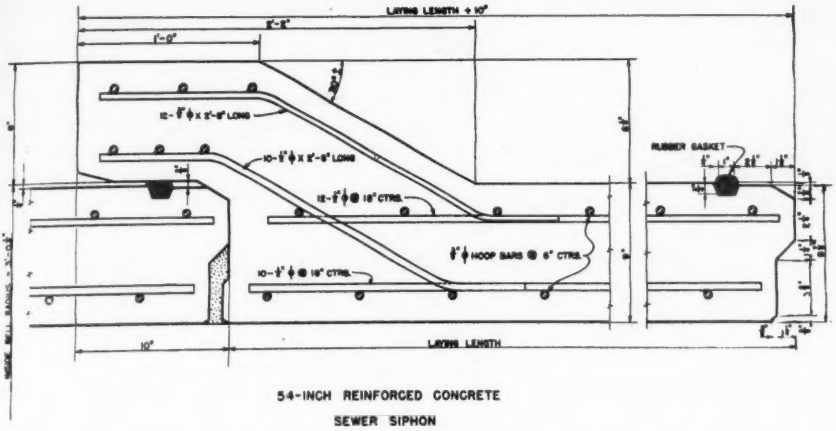

FIGURE 10.—Proposed reinforced concrete sewer joint to be used at inverted siphon.

were set up by the Port of Portland and the U. S. Army Engineers in order that river traffic will not be adversely affected.

The siphons are to be made by constructing two precast concrete pipe lines; one line is to be 54 and the other 72 inches in diameter. The pipe probably will be cast in lengths of 20 ft. and two units assembled on shore and then lowered as a single unit into a prepared trench in the bottom of the slough. The type of joint has not been definitely selected but favorable consideration is being given to the one shown in Figure 10.

The Intercepting System

The final location of the interceptor system is shown in Figure 11. The relative lengths of open cut and tunnel are indicated. The main tunnel through the Peninsula is a little over 17,000 ft. in length and is to be constructed as an 8-ft. horseshoe section of monolithic concrete. The tunnel immediately ahead of the main pumping station at Sullivans Gulch is to be a 6-ft. horseshoe sewer. The other tunnels shown will contain either precast concrete sewer pipe or a special monolithic section approximately 3.5 by 5.5 feet. The large sewers in open cut are to be semi-elliptical in section, the largest being 8.5 ft. in diameter from the end of the Peninsula tunnel to the treatment plant. The outfall is to be an 8-ft. semi-elliptical sewer except for the siphons.

Since the Portland sewers carry both sanitary sewage and storm waters from streets and roofs, diversion structures have been designed to take the maximum of the sanitary sewage plus allowances for infiltration, future growth, and a small amount of the initial storm water. A small amount of storm water is to be intercepted, since it seemed desirable to divert the initial washings of the streets to the interceptor system. At times of heavy storm runoff it is anticipated that the interceptor system may be filled. This permits carrying the greatest practicable volume of combined sewage to the Columbia River. As the city grows and the sanitary flow increases the volume of this excess storm water will be reduced.

Diversion Devices

The problem of the diversion of sanitary sewage from the combined sewers of the city made it desirable to have a diversion device that would limit the volume of sewage diverted

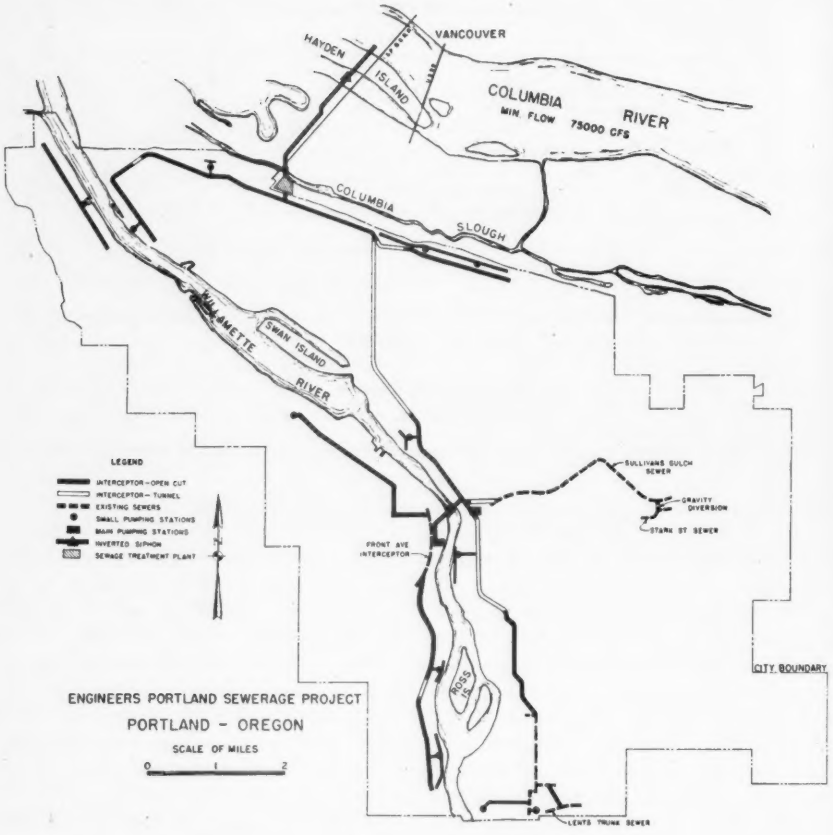

FIGURE 11.—The intercepting sewer location.

and prevent most of the grit from entering the interceptor system. Various devices for the diversion of sanitary flow were considered. Among these were those developed by the cities of Milwaukee and Chicago, and the various devices that can be purchased through manufacturers. The Chicago tilting gate unit is an improved Milwaukee diversion device. These gates can limit the flow to the interceptor system reasonably satisfactorily, but they divert practically all the grit into the interceptor.

Inasmuch as the known diversion devices were not designed to prevent grit from entering the interceptor, a new type was proposed and model studies of its actions were made in a local hydraulic laboratory. This device consisted of a horizontal orifice placed along the side of the sewer and at the same elevation as the sewer invert. To reach the orifice the sewage backed up behind a dam in the main sewer channel and flowed over a long curved lip which had its crest about $\frac{1}{12}$ of the sewer diameter above the invert. Any grit in suspension would, of course, be carried over and into the interceptor. However, the heavier grit on or near the bottom would be prevented from passing over the lip into the interceptor. As the storm flow increases and overflows the dam, the grit previously accumulated be-

hind the dam will be washed over it and into the river.

The model studies proved successful and a full scale diversion structure was constructed in the 36-in. by 36-in. Kenton sewer. The diversion consisted of a U-shaped structure in the side of the sewer. Figure 12 shows the diversion structure and orifice plate in operation. Figure 13 shows a much larger flow passing through the orifice. The orifice plate shown is 16 inches in diameter and is placed on top of the flange of an 18-in. cast-iron pipe 90° elbow which is connected to an 18-in. diversion sewer. It was

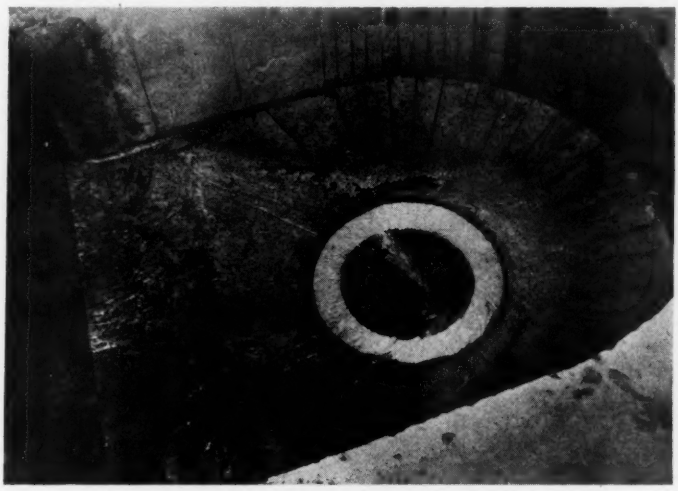

FIGURE 12.—Full scale diversion model for the Kenton Sewer with 16-in. orifice plate in position.

FIGURE 13.—The Kenton sewer diversion structure showing a high rate of flow passing through the diversion orifice.

found that without any orifice plate the 18-in. sewer with a normal slope had a capacity greater than the orifice with the vortex. With the large diversions (18-in. orifice plates and larger) it may be desirable to reduce the vortex action which can be done and thus the discharge through the orifice increased by increasing the ratio of the orifice size to that of the surrounding chamber.

Small Pumping Stations

Twelve small pumping stations are required to lift the sanitary sewage originating below the gravity diversions to the main interceptor. These are to be fully automatic. All consist of one set of duplex units which automatically screen the sewage. Some of the stations have additional units to pump excess flows caused by infiltration and storm water entering the system. Where possible the storm flow units pump the water directly to the river.

Figures 14 and 15 show the general design of the Montana Street Pumping Station, which is fairly typical. This station consists of the duplex units plus one 2,000 g.p.m. pump that is anticipated to be required during excessive storm flows. The sewage is screened prior to passing to the wet pit by the regular screens of the duplex units or by a horizontal overflow screen providing sufficient capacity for the maximum anticipated flow.

A few of the small stations have two wet pits. The duplex units operate from one wet pit and the storm pumps from the other. The storm pumps are large non-clog units and are to be protected by coarse screens with 2½-in. openings.

The twelve small stations will not require an attendant except for routine visits to see that all equipment is operating satisfactorily and to remove screenings accumulated on the coarse screens where these are used. From an operating standpoint it has seemed desirable to provide that all small pumping stations require as little maintenance and attendance as possible.

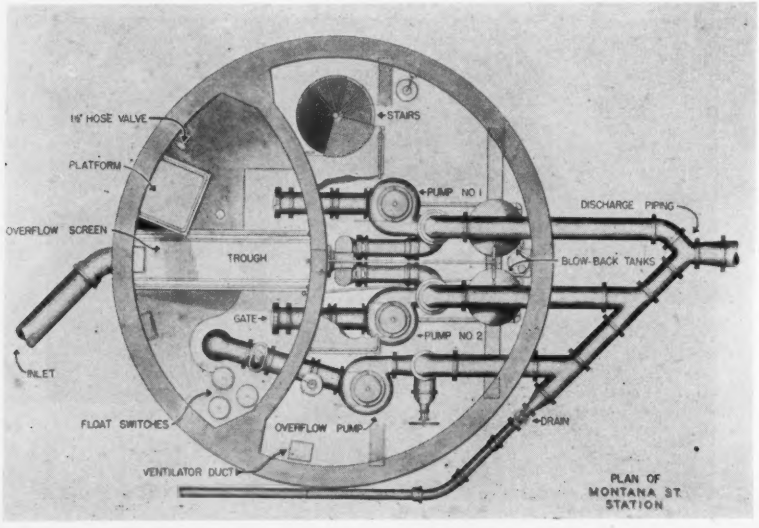

FIGURE 14.—Plan of the Montana Street pumping station.

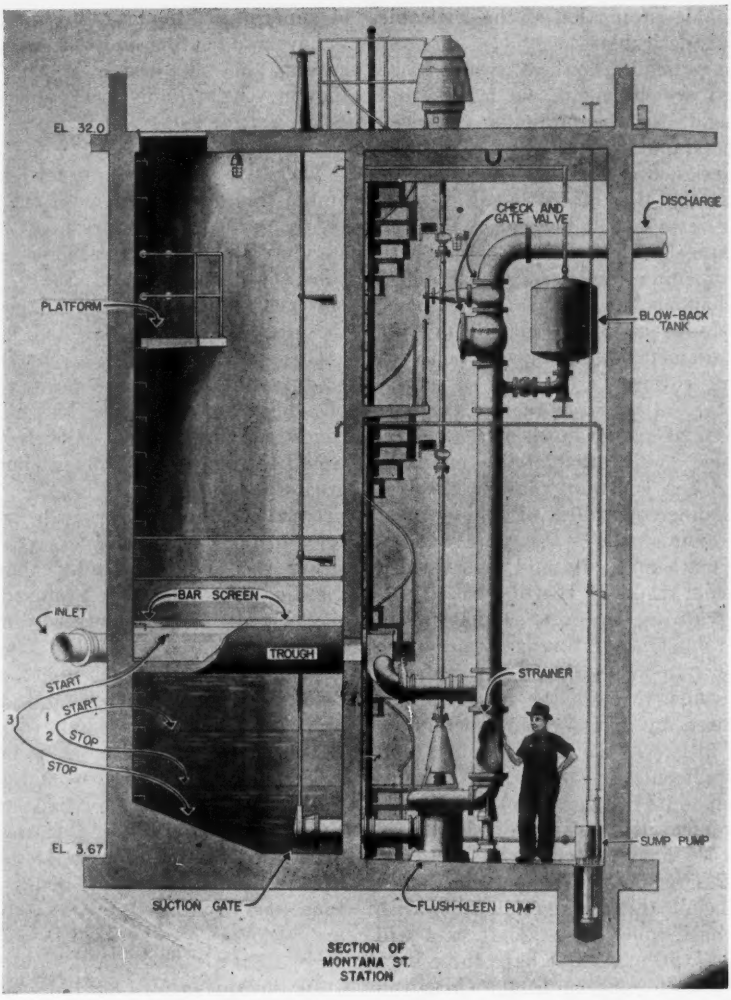

FIGURE 15.—Sectional elevation of the Montana Street pumping station.

Main Pumping Stations

There are to be two main pumping stations in the system: the Ankeny Street station which has been described and the Sullivans Gulch station. The sewage originating south of Sullivans Gulch on the east side will be lifted approximately 32 ft. at the Sullivans Gulch pumping station. From here it will flow to the Columbia River by gravity. This station is to have a maximum capacity of 60 m.g.d.

Treatment of Sewage

The sewage from the city is to have primary treatment as recommended by the Wolman Board. With a minimum flow of 75,000 c.f.s. the Columbia River has a tremendous volume for the disposal of sewage by dilution. It is agreed by the health authorities and by most of the engineers that have been connected with the local problem, however, that primary treatment to remove the floating material and a

reasonable proportion of the settleable solids is desirable.

The estimated flows of sewage to be treated are 40 m.g.d., 60 m.g.d., and 75 m.g.d. for the minimum, average, and maximum, respectively. The units are designed hydraulically to handle a maximum flow of 155 m.g.d.

The sewage will be passed through mechanically cleaned bar screens with 1-in. openings followed by standard grit channels and sedimentation basins. The sludge is to be digested in four 90-ft. diameter digesters equipped with floating covers.

In the outlet end of each of the four trapezoidal grit channels is a specially designed weir that will maintain virtually a constant velocity through the channel regardless of the depth of flow. The shape of this weir was derived mathematically and then verified by model studies. It will have adjustable features, however, so that it can be set by trial if this is found to be necessary.

The flow through the plant will be measured by two Venturi meters located between the grit channels and the sedimentation basins, with registration to be in the control building.

Sedimentation capacity is based upon 1½ hours detention at the average design flow. The settling tanks will be of the rectangular type with four basins 58 ft. by 225 ft. and will be 10 ft. deep, each to have three bays with collector mechanisms. Cross collectors are to be provided to concentrate the sludge to the sludge wells.

Sludge is to be pumped by pneumatic ejectors to a preheating tank from which the steam-heated raw sludge will be pumped to the digesters. Four digesters of 90-ft. diameter are to be provided. Each digester may be operated as a primary or secondary unit. It is anticipated that three units will be used as primary tanks and the fourth as a secondary. All digesters are to be equipped with devices for the continual or intermittent withdrawal of supernatant liquor. It is proposed to have two floating and two gas holder covers, and the design is such that they may be made by local fabricators.

Disposal of Sludge

There are very few unusual features of the treatment plant or of the process to be used. In all respects it is a standard primary treatment plant. One special feature of the process, however, is the proposed method for the disposal of the digested sludge.

Open drying beds were not considered feasible due to the large volume of sludge expected and the climatic conditions of the area. Covered beds would be an improvement but the area still would have to be large. The production of fertilizer is being left for future consideration.

For the early periods of operation the digested sludge will be mixed with the effluent and discharged into Columbia River. A system of sampling and analysis will be set up to gather data as to the efficiency and desirability of this method of sludge disposal. Reference is made to a paper on this subject by A. M. Rawn and E. J. Candel, presented before the Sanitary Engineering Division of the American Society of Civil Engineers at its 1947 Spring Meeting in Phoenix, Arizona (4).

Construction

In the spring of 1946 bids were invited on the intercepting sewer and some deep sanitary sewers along Columbia Slough. This included the short tunnel and all sewers along Columbia Slough east of the main interceptor (Figure 11). The low bid was $492,000, which was 42 per cent above the Engineer's estimate. This same unit then was divided into three contacts and bids again invited in June, 1947. The Engineer's estimate was revised and placed at $460,000, and the low bid at the second invitation was $458,000.

At the same time bids were received on the two small pumping stations for this unit of the interceptor system. These bids were $15,000 per station above the Engineer's estimate of about $44,000. The City Council accepted the bid for the sewers and rejected the bids on the pumping stations. Bids on these stations will be invited later, probably with some modification of the schedules.

Based upon the estimates made following the first invitation of bids the total cost of the project is anticipated to reach $14,500,000. Had it not been for economies in the final plan over that originally contemplated, the present anticipated cost of the project would exceed the above estimate by some 3 million dollars.

The first work has been started. The construction program should continue with additional contracts awarded as the work progresses. It is unlikely that bids will be called faster than local contracting firms can absorb this particular type of work.

Acknowledgments

The design of the project is being carried on as a joint venture between the firms of John W. Cunningham & Associates and Stevens & Koon, both of Portland, Oregon.

Special acknowledgments are due the following for information and assistance in securing data for this paper: R. E. Koon, John W. Cunningham, Ben S. Morrow, Frank T. Koehler, Wilfred Jupenlaz, and W. C. Nicholas.

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MANOMETRIC MEASUREMENT OF THE BIOCHEMICAL OXYGEN DEMAND OF SEWAGE*

By D. H. Caldwell and W. F. Langelier

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The manometric technique suggested in the title of this paper relates to a group of methods now firmly established and widely used in microbiology and in the study of tissue metabolism. Some of these methods have been tried in sewage research, but to date little progress has been made in adapting them for routine use in sewage laboratories. It is the purpose of this paper to describe the characteristics of this type of apparatus and to discuss its adaptability to the estimation of the pollutional strength of sewage and similar wastes.

The studies were conducted in the Sanitary Engineering Laboratories of the University of California in cooperation with the Bureau of Sanitary Engineering of the California State Department of Health. The Bureau, under the direction of C. G. Gillespie, purchased much of the equipment and lent the services of the first-mentioned author. The work was begun in 1942, and most of the data presented herein were completed the following year. At that time the work was interrupted, and it is only now being resumed. The studies are of a preliminary nature, but it is believed that the conclusions already derived are of sufficient importance to warrant publication at this time.

Standard Method for the Measurement of B.O.D.

The biochemical oxygen demand of sewage can be defined as the free oxygen consumed during its aerobic biochemical stabilization under specified conditions of time, temperature, and dilution. The standard test procedure, originally proposed for sewage plant effluents, is subject to several well-known defects or imperfections, especially when applied to crude sewages and trade wastes. In spite of these, however, the test results are regarded as the best available criteria of sewage strength for use in estimating plant loading as well as in estimating the required dilution of plant effluents. Many long and laborious investigations have been made in attempts to improve the method and to interpret the true significance of the test results.

The standard test procedure requires the use of several varying dilutions of the sample with specially prepared aerated water. These dilutions are incubated usually for a period of five days at 20° C. The B.O.D. is calculated from the loss of dissolved oxygen during incubation. The need for variable dilutions arises from the limited capacity of water to hold oxygen in solution. This is an objectionable feature of the test procedure, not only because it involves extra work and incubator space but also because it frequently happens that when the results of two different dilutions are compared they do not agree, and an arbitrary selection of the most probable correct result must be made. Another serious objection to the standard procedure is that the recommended incubation period of five days is inconveniently long and thus sometimes

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precludes the use of the data in controlling certain of the daily operations of a treatment plant. It will be shown that the proposed manometric method, partly because it provides a more adequate reservoir of oxygen and thereby eliminates the necessity for high dilutions, overcomes several of the more objectionable features and deficiencies of the standard method.

Principles of Manometric Measurement in Cell Respiration

Instruments designed for the measurement of small quantities of gas, either absorbed or evolved in biochemical reactions, are called "respirometers." In general, the apparatus comprises a constant temperature water bath equipped with a shaking mechanism to which are attached a number of sample flasks, each with a manometer for indicating changes in gas volume. Basically, four different types of apparatus have been perfected and are in common use. They can be designated as the Haldane, Barcroft, Warburg, and Fenn types. The Fenn type of apparatus, strictly speaking, is volumetric and not manometric but is included here because of similarities in design and use.

The Haldane apparatus is a constant-pressure type and, because of its relatively cumbersome bulk and inconvenience in use, it is the least well-adapted for measurements of cell respiration. As with the Orsat gas analysis apparatus, a leveling bulb is an essential part of the unit. In its later modifications, an automatic compensation for temperature and barometer changes is provided by the inclusion of a control flask and a second manometer.

Reviews of modern practice in manometric techniques employed in measuring cell respiration often fail to mention the Haldane apparatus. Reference is made to it here because various modifications of the Haldane apparatus have been used by Adeney (1), Sierp (2), Lovett and Garner (3), Falk and Rudolfs (4), Heukelekian (5), and others for measuring the B.O.D. of sewage. These methods possess some advantages over the standard dilution method, especially as applied to industrial sewage; but the authors believe that the Barcroft and Warburg methods, because of their greater accuracy and adaptability in measuring rates of reaction and because they afford greater convenience in making a number of parallel determinations, will be found to be considerably more useful in the sewage works laboratory.

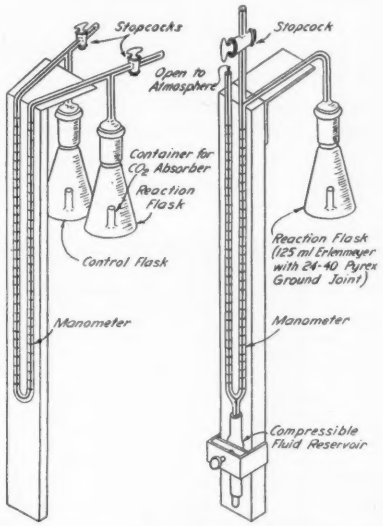

FIGURE 1.—The Barcroft Differential Manometer (left).

FIGURE 2.—The Warburg Constant-Volume Manometer (right).

The Barcroft monometer is illustrated in Figure 1. It consists essentially of a reaction flask and a control flask, interconnected with a U-shaped graduated capillary manometer equipped with stopcocks to equalize pressure in each flask at the start of a test. The flasks are commonly of 35-ml. capacity and each has a small compartment for holding a CO_2 absorb-

ent. In use, a measured volume of the sample of about 1 to 3 ml. is placed in the reaction flask, and a measured volume of clean water is placed in the control flask. With both stopcocks open, the unit is attached to the shaker, and the flask contents are brought into equilibrium with the atmosphere at the temperature of the bath.

It will be seen that slight changes in the temperature of the water bath in which the flasks are submerged will affect the pressures in both flasks equally. Also, after the stopcocks are closed, changes in barometric pressure will not alter the pressures inside. Accordingly, after any interval of time, the difference in the levels of the fluid in the two arms of the manometer is directly related to the difference in oxygen consumption in the two flasks. In order to calculate the value, it is merely necessary to multiply the difference in manometer readings by the "flask constant." This constant is readily obtained either by experiment or by calculation, and for a given pair of flasks it will vary only with the volume of sample used.

The practicability of measuring the B.O.D. of sewage with this type of apparatus is believed to have been first demonstrated in 1936 by Wooldridge and Standfast (6) in England. These authors made numerous tests of sewage and sewage effluents, and measured the activity of activated sludge. Their work was thorough and conclusive. That it has not received more attention in this and other countries is surprising.

The Warburg constant-volume manometer, which the present authors selected for its possible adaptation to sewage studies, is illustrated in Figure 2. It differs from the Barcroft differential manometer in that it comprises a single reaction flask attached to a U-

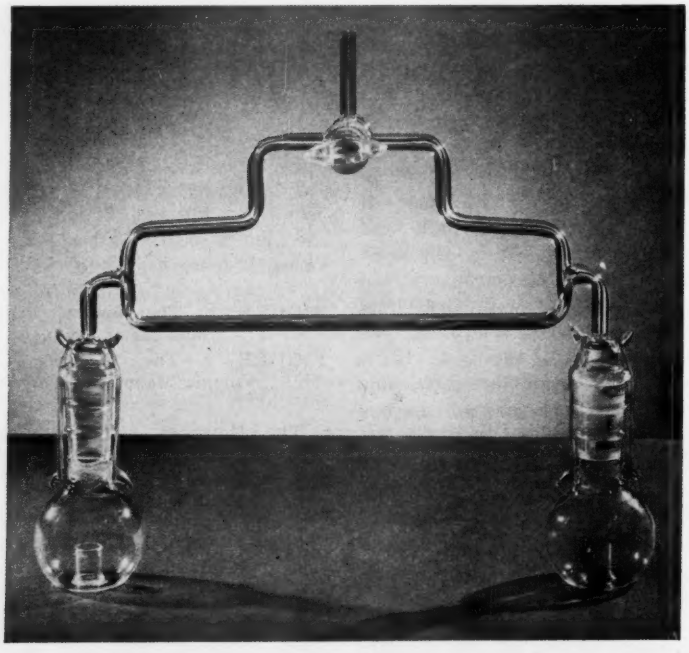

FIGURE 3.—Differential type volumeter specially designed for sewage testing.

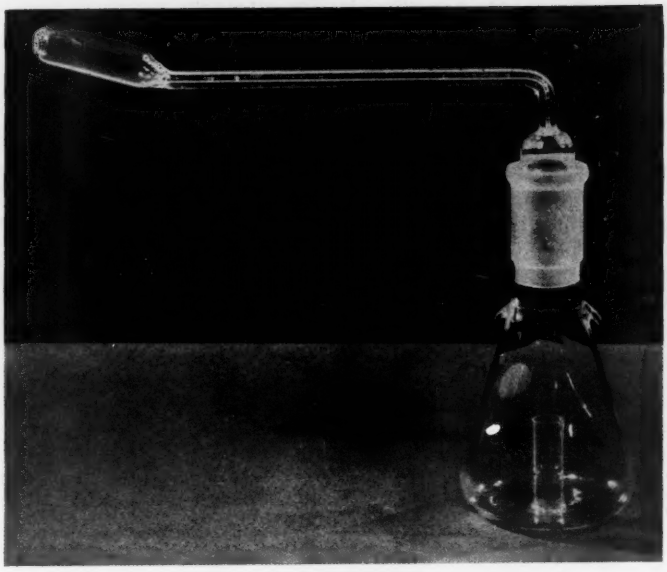

FIGURE 4.—Simple volumeter specially designed for sewage testing.

shaped capillary manometer, the other end of which is open to the atmosphere. In practice, a number of these manometers is used in conjunction with a single independent control flask and a manometer for barometric and temperature compensation.

In the use of the Warburg manometer, the fluid in the closed arm is adjusted to a constant level at the time of each reading. This is readily accomplished by the provision of a small compressible fluid reservoir located at the bottom of the "U." The level of the fluid in the open arm is then read, and to this reading is added any change in atmospheric pressure as indicated by the control flask manometer. As with the Barcroft manometer, the reading, multiplied by the flask constant, gives the weight or volume of the oxygen absorbed. The degree of precision obtainable is equal to that of the Barcroft manometer, and the method is equally applicable for measuring rates as well as total gas produced or consumed. A distinct advantage of the Warburg manometer relates to compactness. A standard water bath, 28 by 12 in. in plan, will accommodate 14 Warburg manometers (13 samples), whereas it will accommodate only 8 Barcroft manometers.

The Fenn respirometer embodies the basic principles of the Barcroft apparatus. In this instrument, however, the two flasks are connected by a horizontal capillary tube containing an oil drop, the movement of which is proportional to the gas absorbed. This type of apparatus has been developed as a micro instrument for the estimation of minute quantities of gas exchange. The authors believe, however, that it can be used to advantage in sewage testing, and work with it has been started (Figures 3 and 4).

Since most of the work to date has been with the Warburg type of manometer and since no published references to its previous use in the analysis of sewage, sewage sludges, or sewage and

trade-waste mixtures have been found, the theory and use of this apparatus is discussed in detail.

Adaptation of Warburg Apparatus to the Determination of B.O.D.

The first apparatus used in these studies was a standard 14-manometer unit, maufactured by the American Instrument Company of Silver Springs, Md. This apparatus comprises a water bath with electric thermoregulator and motor stirrer. The manometers are mounted on supports which impart to them a reciprocating motion necessary in maintaining oxygen saturation of liquid specimens. The only alteration found desirable was the replacement of the standard 15-ml. flasks by larger 125-ml. flasks as shown in Figure 2.

During the course of the studies, a second apparatus holding 8 manometers was constructed from standard laboratory equipment (Figure 5). This unit comprises a circular glass water bath 12 in. in diameter and equipped with a 300-watt heating element, motor stirrer, and thermoregulator. The manometers were made locally from Pyrex capillary tubing of 1-mm. bore and standard-taper 125-ml. pyrex flasks. These are mounted on vertical graduated supports attached to the rim of a revolving circular support. In operation, the manometers are subjected to a reciprocating motion by a 1/50-h.p. electric motor with speed reducer and simple crank mechanism located underneath the manometer support.

Theoretical Principles

The theory of the Warburg manometer, as used in the measurement of B.O.D., involves the following considerations:

Let v = the volume of oxygen consumed in ml. at N.T.P.
w = the corresponding weight of oxygen consumed in p.p.m.
h = the corresponding reading of the manometer in cm. of water
V_g = the total volume of gas in the flask, connecting tube, and manometer, to the level of the manometer-fluid reference point, in ml.
T = absolute temperature of bath ($t°$ C. + 273)
P = initial oxygen pressure in flask in cm. water
P_0 = normal pressure in cm. water (1,030)
α = volume of oxygen, at N.T.P., absorbed by one ml. of water at temperature T, when the pressure of the dry gas is 760 mm. Hg, in ml.

From definition of terms,

Oxygen initially present in gas

$$\text{space} = V_g \frac{273}{T} \frac{P}{P_o}.$$

Oxygen initially dissolved in

$$\text{sample} = V_f \alpha \frac{P}{P_o}.$$

Assuming complete absorption of CO_2 evolved during test,

Oxygen finally present in gas

$$\text{space} = V_g \frac{273}{T} \times \frac{P - h}{P_o}.$$

Oxygen finally present in

$$\text{sample} = V_f \alpha \frac{P - h}{P_o}.$$

Since the total volume of oxygen finally present must equal the total volume initially present less v, the volume of oxygen consumed,

$$\frac{P - h}{P_o}\left(V_g \frac{273}{T} + V_f \alpha\right) = \frac{P}{P_o}\left(V_g \frac{273}{T} + V_f \alpha\right) - v$$

from which

$$v = h \frac{V_g \frac{273}{T} + V_f \alpha}{P_o}. \qquad (1)$$

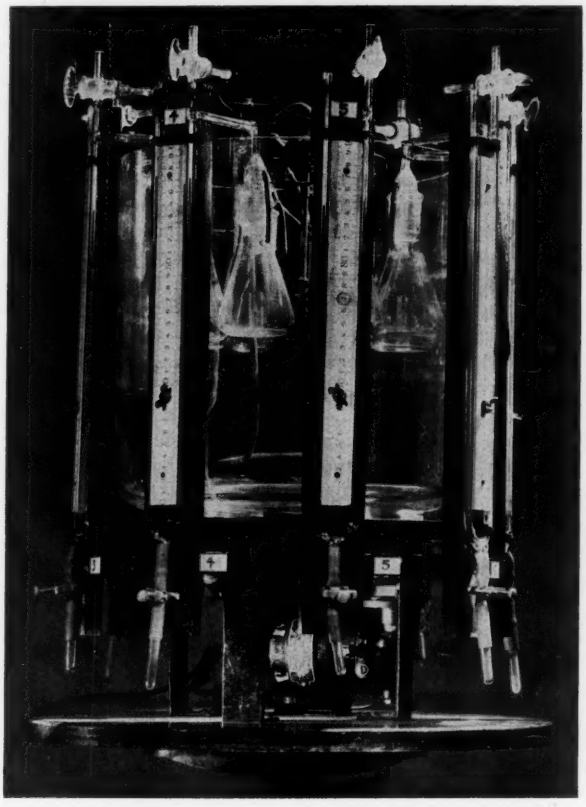

FIGURE 5.—Circular Warburg apparatus made from standard laboratory materials.

In this equation v is the oxygen consumed, in ml. In order to express the results in parts per million by weight,

$$w = \frac{3.2 \times 10^7}{2.2 \times 10^4} \times \frac{v}{V_f},$$

or

$$w = \left(\frac{273 V_g}{T P_o} + \frac{V_f \alpha}{P_o} \right) \times \frac{1430}{V_f}.$$

If V_f does not exceed 10 per cent of V_g, the value of the term $\frac{V_f \alpha}{P_o}$ will be less than 0.5 per cent of the term $\frac{273 V_g}{T P_o}$, and can be neglected. Also, if the temperature of the bath is held at 25° C.,

$$w = \frac{V_g}{V_f} \times \frac{2.73 \times 10^2 \times 1.43 \times 10^3}{2.98 \times 10^2 \times 1.03 \times 10^3},$$

or

$$w = h \left(1.27 \frac{V_g}{V_f} \right). \qquad (2)$$

The expression within the bracket is designated as the "flask constant," and for a given flask it will vary only with the volume of sample used and the temperature of the bath.

It should be noted that in the above considerations the effect of the nitrogen of the air is neglected. This is because its partial pressure in the air space and

its concentration in the sample remain constant throughout the test period and therefore would cancel out from the equation.

Calibration of Manometers

The manometer units (Figure 2) are designed for the use of air rather than of pure oxygen as the means of oxygen supply. The removable reaction flasks are made with standard taper joints and are interchangeable. In practice, however, since it is necessary to know the exact air volume of each manometer unit, each flask is numbered and calibrated to correspond to a particular manometer.

Prior to the initial use of a manometer unit, it is necessary to calibrate it for total air space in the reaction flask and manometer under the conditions of use. This is easily accomplished by weighing the unit, both when empty and when filled with water of known temperature, after which a correction is made for the volume occupied by the sample and the absorbent to be used in the test procedure.

The gage fluid used in these studies was distilled water, to which had been added a wetting agent, a few drops of fluorescein as coloring agent, and a trace of thymol to prevent mold growth.

Two types of CO_2 absorbent containers were used. The one shown in Figure 2 is made by fusing a 2.5-ml. shell vial to the bottom of the reaction flask. This type of container is suitable for holding a liquid absorbent as, for example, 10 per cent KOH. A detachable container suspended inside the flask and containing soda-lime was used in some of the studies. Both types proved to be about equally satisfactory.

Preliminary Studies

The standard specifications of the B.O.D. test involve a much longer incubation period than has been customary in the use of the Warburg apparatus. Accordingly, at the outset of this investigation, it was necessary to consider certain factors which would affect the precision or dependability of the method as applied to sewage testing. The factors which seemed to demand particular attention were (1) estimates of appropriate sample volume and its relation to the size of the reaction flask, (2) rate of oxygen diffusion into liquid as related to shaking speed, (3) removal of CO_2 or other byproduct gases, (4) desirability of buffering sample and (5) reproducibility of results. Most of these factors, as related to general respirometer work, are discussed in manuals on manometric techniques by Dixon (7) and by Umbreit, Burris and Stauffer (8).

Sample and Flask Volume

Reference to Equation 2 shows that when the ratio of air to liquid volumes equals 10, a maximum permissible manometer reading of 30 cm. indicates an absorption of $30 \times 1.27 \times 10 = 381$ p.p.m. of oxygen. Thus if a standard Warburg flask of approximately 15-ml. total capacity were used in sewage work, a sample volume of only 1 ml. or 2 ml. would represent the maximum volume of undiluted normal sewage which could be used without exceeding the capacity of the manometer. Although sewage samples of such volume can be accurately measured, it seemed that in routine sewage testing the use of larger samples would be advantageous from the standpoint of both flexibility and ease of manipulation, without sacrifice of precision. Accordingly, the manometers were equipped with relatively large flasks. As shown in Figure 2, standard taper 24/40 interchangeable Erlenmeyer flasks of 125-ml. capacity were employed. These flasks and their connecting joints provide a total capacity of approximately 150 ml. Assuming that the 30-cm. manometers can be read accurately to the nearest millimeter,

the range of the apparatus in terms of B.O.D. for varying sample volumes can be calculated by the use of Equation 2. These data are shown in Table I.

TABLE I.—Range of B.O.D. Using Warburg Manometers Fitted with 125-ml. Reaction Flasks

Sample Volume (ml.)	Air Volume (ml.)	B.O.D. Range (p.p.m.)	B.O.D., P.P.M. per Mm. of Scale Division
10	140	0–500	2.0
20	130	0–230	1.0
30	120	0–140	0.5
40	110	0–100	0.4
50	100	0–70	0.3
75	75	0–35	0.2

Oxygen Supply and Demand as Related to Shaking

Because of the slight solubility of oxygen in water which is in contact with air at atmospheric pressure, under the conditions of the test it is essential that the rate of oxygen demand shall not exceed the rate of supply by diffusion. Dixon and Elliott (7) have investigated this matter for general respirometer work. They report that in standard Barcroft flasks—not unlike the flasks used in these Warburg units—shaking at the rate of 210 oscillations per min. was adequate to satisfy a maximum oxygen demand rate of 0.8 ml. per hour. By substituting this value in Equation 1, it is found that it corresponds to a maximum change in manometer reading of 6.5 cm. per hour under the conditions of test procedure. That is, test readings approaching this value would indicate that the demand for oxygen could be in excess of the rate of supply by diffusion. If a standard 10-ml. sample is used, substitution of this limiting value of h in Equation 2 indicates an equivalent 1-hr. B.O.D. of 116 p.p.m. Assuming the normal reaction velocity, the 5-day demand could be expected to equal approximately 100 times the maximum hourly demand. It can be concluded therefore that the rate of oxygen supply as stated by Dixon is considerably greater than the maximum rate of demand likely to be required under the procedure described.

Because provision for continuous mechanical shaking somewhat complicates the design of the manometric apparatus, and because (as in the Sierp method) attempts have been made to employ modifications of the apparatus without continuous shaking provision, it seemed desirable to obtain by direct experiment a closer estimate of the shaking requirements. The results of 2 series of experiments designed for this purpose are shown in Figures 6 and 7. In Figure 6 it will be noted that when the shaking speed was set at 75 oscillations per min., identical

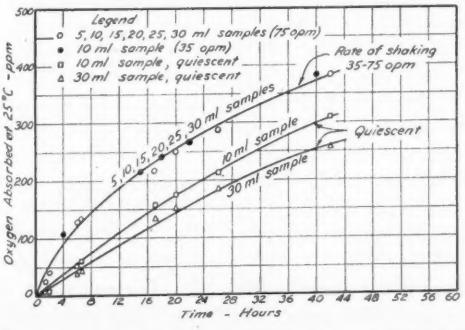

FIGURE 6.—Results of experiments with Warburg apparatus designed to establish limiting rates of oxygen demand measurement for various degrees of shaking.

values of B.O.D. were obtained for all sample volumes tried. This can be taken to indicate that the supply of oxygen was equal to or greater than that which the maximum demand indicated. When the shaking speed was

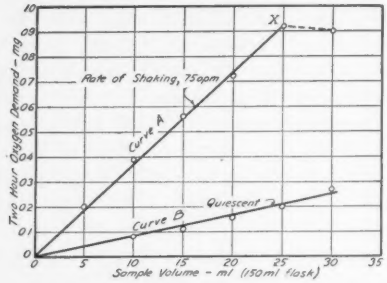

FIGURE 7.—Data from Figure 5 replotted to show limiting 2-hr. oxygen demand with and without shaking.

reduced to 35 oscillations per min., the demand for the 10-ml. sample was not changed, thus indicating that for normal demands the lower shaking speed was ample. That some degree of continuous shaking is required, however, is clearly indicated in the curves representing quiescent conditions. In the absence of shaking, the results are low. This appears to be occasioned by an excessive demand during the first few hours of the test period, when the rate of consumption is at a maximum.

For the purpose of showing the supply-and-demand relationship during the critical first hours of incubation, some of the data shown in Figure 6 have been replotted in different form in Figure 7. In this figure, the uptake of oxygen at the end of 2 hours has been plotted against volume of sample, *i.e.*, increasing demand. For Curve A, the flasks were shaken at a rate of 75 oscillations per minute. It will be noted that the relationship between the 2-hour demand and the volume of sewage present is linear only up to point *X*. Below this point, the true demand has been measured; beyond this point, the rate of oxygen diffusion into the sewage is obviously less than the rate of demand. The conclusion to be drawn from this experiment is that, for the 75-o.p.m. rate of shaking in the Warburg apparatus as modified for sewage work, the maximum rate of absorption is approximately 0.9 ml. of oxygen in 2 hours, which for a 10-ml. sample is equivalent to a 2-hour B.O.D. of 90 p.p.m.

In this experiment, the demand variable was obtained by the use of increasing volumes of sample, which had the effect of changing the air-liquid interfacial area. Accordingly, in a strict sense, the relationship shown between oxygen supply and demand is not general but is specific only for the volumes of samples actually used. Another limitation of the data is that in Curve A only one point occurs beyond the break, and therefore the trend of the curve is not definitely established. The data nevertheless are of value because they indicate the maximum capacity of the manometers under conditions of use.

Absorption of Carbon Dioxide

The theory of the Warburg method as applied to the determination of B.O.D. assumes that, following the initial period of equilibration, only oxygen and carbon dioxide are involved in the gas exchange and also that the effect of the latter can be completely eliminated by the use of 1 ml. or less of an alkali absorbent placed in a separate compartment within the flask. With respect to the former, Wooldridge and Standfast (6) aerated sewage for considerable periods of time under conditions which enabled the analysis of the air by standard gas analysis procedures. They obtained negative tests for hydrogen, hydrogen sulfide, methane and nitrogen, and concluded that under the ordinary conditions of the B.O.D. test there is no reason to suspect that gases other than oxygen and carbon dioxide are involved.

There is abundant evidence to prove

that errors caused by the incomplete absorption of CO_2 are negligible. Dixon and Elliot (7) have shown that with the use of "KOH paper" the accumulation of CO_2 was negligible, provided the rate of production was not greater than 1.0 ml. per hour. Corbet and Wooldridge (9) found that in sewage testing the special precaution of using impregnated paper to extend the alkali contact surface was unnecessary and that equally good results were obtained by the original method using only KOH solution.

Since in the aerobic oxidation of sewage the CO_2 produced can never be greater than the equivalent of the oxygen absorbed, the maximum rate of CO_2 production from this source under the specified conditions would be appreciably less than the allowable rate as stated above. Another factor, however, is involved in sewage testing—the free CO_2 present in the sample at the start of equilibration.

The concentration of free CO_2 in sewage is approximately represented by the equation.

$$p(CO_2) = p(HCO_3) + pH - pK_1, \quad (3)$$

where $pK_1 = 6.3$ (25° C.). Thus, in a sample of sewage with $pH = 70$ and total alkalinity of 400, the free CO_2 will equal 34 ml. per liter. A 10-ml. sample would contain 0.34 ml. which, if released instantaneously, would require an equilibration period of perhaps 20 min. for its complete absorption.

Since in the Warburg apparatus the pH of the sample approaches 8.2 during equilibration and remains at about that level throughout the test period, it would appear advantageous to buffer the sample at this pH at the outset. This would eliminate the hazard of incomplete CO_2 absorption during equilibration.

A second possibility lies in buffering the sample to a pH level at which the sample will be continuously in equilibrium with the initial CO_2 pressure in the air space, thereby eliminating the need for an absorbent. The equation which gives the pH of a bicarbonate solution which is in equilibrium with a given CO_2 partial pressure is as follows:

$$pH = pK_1 + \log (HCO_3) - \log P_{CO_2} - \log \frac{\alpha}{22.4 \times 760}. \quad (4)$$

In this equation, $pK_1 = 7.3$ and $\alpha = 0.76$ at 25° C. Assuming a maximum concentration of bicarbonate equal to 0.01 mols per liter and the partial pressure of CO_2 equal to 0.22 mm. Hg., the equilibrium pH, at which CO_2 would be neither released nor absorbed by the sample, is found to equal 9.2. There is evidence to indicate that at this high level of pH there would be some decrease in the rate of oxidation. Wooldridge and Standfast have shown this to be the case; but in their experiments a phosphate buffer was used at pH 8.0, whereas a borate buffer was used at pH 9.0. When borate was used at both pH 8.0 and 9.0, there was no decrease in the rate, although the rates were considerably lower than for the phosphate-buffered samples at pH values of 8.0 and lower. In the present studies, preliminary experiments indicate that borate additions decreased the rate of sewage oxidation. Accordingly, pending further investigation, it is regarded as preferable to buffer the sample with phosphate at a level not higher than 8.2.

Reproducibility of Results

Dixon (7) states that oxygen uptake determinations on homogeneous bacterial cell-suspensions by the direct method are usually found to agree within 2 per cent. The authors have found that this holds reasonably true with sewage samples. In Table II are given the results of parallel determinations on samples of crude and settled sewage for variable holding periods.

TABLE II.—Results of Replicate Determinations of the B.O.D. of Two Sewages by the Warburg Manometric Method for Varying Incubation Periods

Source of Sample	Time of Incubation (hours)				
	16	24	40	48	65
Crude sewage					
Test 1	313	407	541	578	645
Test 2	313	407	520	556	633
Test 3	306	392	533	568	628
Test 4	309	395	538	573	637
Test 5	315	411	543	580	637
Average	311	403	533	575	636
Average deviation (%)	1.0	1.7	1.3	1.2	0.7
Maximum deviation (%)	1.6	2.7	2.4	3.3	1.4
Settled sewage					
Test 1	178	212	272	295	333
Test 2	177	209	274	293	334
Test 3	173	206	269	287	333
Test 4	186	223	291	324	361
Test 5	182	218	294	319	353
Test 6	185	216	280	308	338
Average	180	214	280	304	342
Average deviation (%)	2.2	2.3	2.9	4.3	2.9
Maximum deviation (%)	3.3	4.2	5.0	6.6	5.6

The average deviation for a 24-hour holding period was 1.7 per cent for the crude sewage sample and 2.3 per cent for the settled sewage sample. The corresponding maximum deviations were 2.7 and 4.2 per cent.

Rate of Oxygen Demand as Influenced by Dilution

When results obtained by manometric and by standard methods are compared, it is found that the manometric results for both rate (k-value) and ultimate demand (L-value) are appreciably higher. The data thus far obtained show that the manometric 3-day values at 25° C. are in general greater than the 5-day values at 20° C. obtained by the standard dilution method. Also, as shown in Table III, it has been found that the 1-day manometric values average approximately 75 per cent of the standard 5-day values. If the so-called normal rate of oxidation at 25° C. ($k = 0.126$), characteristic of the dilution method, were to hold for the manometric method, the 1-day values would be only 33 per cent of the standard 5-day values. Apparently, the velocity of the reaction as it occurs in the manometric method is more than double the standard rate, even allowing for temperature differences.

The manometric method is particularly well adapted for the study of reaction velocity, because all of the variables are subject to ready control, and readings at variable intervals of time can be made without disturbing the sample. When, in the Warburg method, dilution of the sample is made the only variable, it is found that dilution lowers the calculated demand and that the effect is most noticeable at the higher dilutions.

In the use of the standard method employing high dilutions, it is well-known that the short-period (1-day) values are influenced by dilution effects and are therefore unreliable. The standard 5-day values, however,

TABLE III.—Comparison of Manometric 24-Hr. B.O.D. at 25° C. with Standard 5-Day B.O.D. at 22° C.

Sample		24-Hour Manometric	5-Day Standard	M/S Ratio
Sewage	S1	245	330	0.74
	S2	363	493	0.74
	S3	310	520	0.60
	S4	283	400	0.69
	S5	85	96	0.88
	S6	122	133	0.92
	S7	486	535	0.91
	S8	130	177	0.73
	S9	78	102	0.76
	S10	501	660	0.76
Sewage Effluent	E1	145	250	0.58
	E2	18	30	0.60
	E3	102	130	0.78
Vegetable Oil Separator Waste	W1	173	250	0.69
	W2	358	545	0.66
Food Dehydrator Waste	W3	250	311	0.80
	W4	162	200	0.81
	W5	129	173	0.77
	W6	201	227	0.88
	W7	140	177	0.79
	W8	120	150	0.80
	W9	166	201	0.83
	W10	124	155	0.80
Average	—	—	—	0.76

are generally assumed to be independent of dilution. Within the relatively narrow limits of substrate concentrations which can be employed in this method (less than approximately 7 p.p.m. equivalent B.O.D.) the assumption has been found to hold reasonably well, although some investigators contend that dilution decreases while others contend that it increases the calculated result for the undiluted sample (10).

In Figure 8 are shown the results of a series of tests on strong settled sewage in which dilution is made the only variable. In this figure, the results of the manometric method over a wide range of dilution are plotted against time, and the results obtained by the standard method at optimum dilution are included for comparison. All tests were made at 25° C.

It will be noted that if comparable dilutions are used the results obtained by the two methods agree reasonably well. Thus the 3-day value is 515 p.p.m. by the manometric method at a dilution of 1:32, as compared to 490 p.p.m. by the standard method at a dilution of 1:80. The 4-day values are respectively 580 at 1:32 dilution and 551 at 1:80 dilution. When these results are compared with those at the lower dilutions obtainable only by the manometric method, the effect of dilution is clearly shown to result in appreciably lower values.

Figure 9 shows the results of the same experimental procedure, except that the sample material was taken after passage through a trickling filter. In this figure the highest dilution in the manometric tests corresponds more closely to the optimum dilution

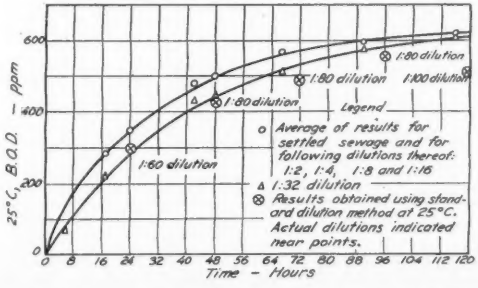
600
400
200
0
25°C, B.O.D. ppm
0 8 16 24 32 40 48 56 64 72 80 88 96 104 112 120
Time - Hours
1:80 dilution
1:80 dilution
1:100 dilution
1:80 dilution
1:60 dilution
Legend
o Average of results for settled sewage and for following dilutions thereof: 1:2, 1:4, 1:8 and 1:16
Δ 1:32 dilution
⊗ Results obtained using standard dilution method at 25°C. Actual dilutions indicated near points.

FIGURE 8.—Comparative results of manometric and standard B.O.D. measurements of settled sewage under varying dilutions.

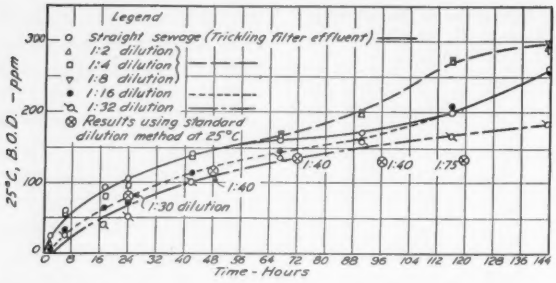

FIGURE 9.—Comparative results of manometric and standard B.O.D. measurements of low-grade trickling filter effluent under varying dilutions.

used in the standard tests. The onset of a nitrification demand is shown to occur well within the 6-day period. Otherwise the results are similar, and the conclusions drawn therefrom are the same.

To show more clearly the effect of dilution as related to time, some of the data shown in Figures 8 and 9 have been replotted in different form in Figures 10 and 11. In these figures, B.O.D. by the manometric method is plotted against dilution, and separate curves are shown for various time intervals. These curves indicate a marked decrease in B.O.D. with increase in dilution, especially for the shorter time intervals. It is unfortunate that the limits of the apparatus at the time precluded the use of higher dilutions more comparable to those used in the standard method, since the curves indicate that the effect would be even more pronounced at the higher dilutions required in that method.

Velocity of Carbonaceous Oxidation

The proportionately higher rate of oxygen demand of undiluted sewage as shown in these experiments is not incompatible with accepted theories of reaction velocity in chemical systems, especially those involving bacterial enzymes. Chemical reactions catalized by enzymes are known to involve adsorptive forces as in flocculation, and it therefore seems reasonable to suppose that factors tending to promote optimum conditions for effective collisions between active surfaces should favor higher reaction rates. Concentration is one such factor, and in the manometric method the conditions of continuous oxygen saturation and

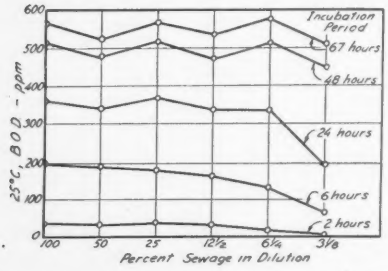

FIGURE 10.—Data from Figure 8 replotted to show the effect of dilution and time upon the manometric oxygen demand of settled sewage.

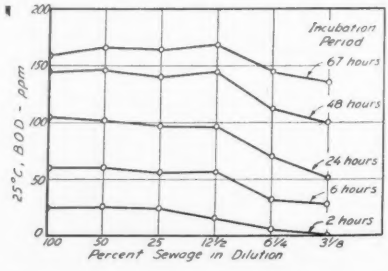

FIGURE 11.—Data from Figure 9 replotted to show the effect of dilution and time upon the manometric oxygen demand of low-grade trickling filter effluent.

gentle motion are undoubtedly also favorable. However, it should not be overlooked that a limit of concentration exists, above which reaction velocity is not proportionately increased. Saturation effects are known to occur, particularly in oxidizing and reducing enzyme systems (11).

The activated sludge and other oxidizing processes of sewage treatment serve to illustrate the effects of concentration. These processes depend upon the precipitation of both enzymes and food material into concentrated sludges and slimes. There is considerable evidence to indicate that in these processes the rate of oxidation of the substrate is considerably higher than the rate represented by the normal *k*-value. Likewise these processes exhibit saturation effects, if certain concentration ratios are exceeded.

Onset of Nitrification

It has been shown that under the conditions of the manometric test procedure, using undiluted samples with constant aeration and mixing, the rate of carbonaceous oxidation is greatly increased. A question arises as to whether the onset of nitrification is advanced in proportion and, if so, to what degree.

In testing primary effluents by the standard dilution method, it has been found that nitrification begins only after 8 to 10 days and that there is little danger of including any of a nitrogenous demand if the incubation period at 20° C. is not prolonged beyond 5 days. In the case of secondary effluents, a nitrogeneous demand can develop well within this period, and Sawyer and Bradney (12) have shown that the onset of nitrification is greatly influenced by dilution. They found an appreciable nitrogenous demand in 10 per cent dilutions of an activated sludge plant effluent but not in a 5 per cent dilution.

In early experiments on the activated sludge process, Bartow and Mohlman (13) showed that the continuous mixing and aeration of even crude sewage in the absence of activated sludge could result in an onset of nitrification after the third day. From these and other considerations, it must be concluded that the onset of a nitrogenous demand will depend not only on the history of the sample but also on the conditions under which the test is made.

Whereas high dilution appears to delay nitrification, the authors have noted that when soluble organic matter is added to sewage, the beginning of nitrification is not advanced as might be expected, but rather it is retarded. Thus there seems to be a critical range in the concentration of carbonaceous matter, on both sides of

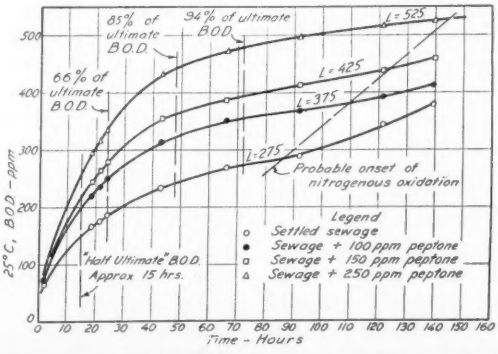

FIGURE 12.—Typical manometric B.O.D. rate curves obtained with Warburg apparatus showing time required for "half-ultimate" and "two-thirds ultimate" values.

which nitrification is delayed. Data on this point are limited, but in Figure 12 it is shown that additions of peptone (17 per cent nitrogen) to sewage have materially retarded nitrification. However, the conditions are not exactly similar, because in this experiment only the concentration of substrate was altered, whereas in the dilution technique both the substrate and bacterial populations are reduced. The need of further study along this line is apparent.

Standardization of Incubation Period

In attempting to express with a single number the results of a variable quantity such as oxygen demand—which increases with time at a rate inversely proportional to itself at any instant—it is often both convenient and practical to denote the quantity by the value which represents one-half of the ultimate value.

If this expedient be applied to the measurement of B.O.D., following the standard procedure and assuming a normal velocity constant of 0.1, a holding period of 3 days would be required. In practice, this incubation period has been regarded as unreliable, because of an initial time-lag of varying duration.

In the use of the manometric method, it has been demonstrated that the initial time-lag is practically eliminated and that the reaction rate is appreciably higher. Accordingly the estimation of the "half-ultimate" (first-stage) B.O.D. would be practical if it could be proven that the reaction is truly monomolecular.

It has been suggested by others, and ably discussed by Phelps (10), that the carbonaceous oxidation of sewage in the presence of activated sludge or trickling filter slimes is a compound reaction and involves two or more simultaneous or chain reactions, each with its own velocity constant. The present studies indicate not only that this theory is valid but also that it can be applied to aerated sewage in either the presence or absence of activated sludge. For the present it is felt that for the purpose of standardization in the application of the manometric method the concept of a "half-ultimate" B.O.D. is impractical and that the designation of a fixed time interval without implication of ultimate value will be found most useful.

In Figure 12 are plotted the manometric demand rates of a sample of plain sewage and of samples of the same sewage with varying increments of peptone. These curves are presented for the purpose of supplementing the foregoing discussion. It will be noted that for the sewages considered the half-ultimate B.O.D. is fairly well approximated by a 15-hour holding period. For purposes of comparison, there are also shown the percentages of probable ultimate demand exerted at the end of 1, 2 and 3 days. When all aspects of the problem are considered, *i.e.*, convenience, reproducibility, absence of nitrification demand, etc., the 24-hour 25° C. incubation period appears to be the most satisfactory index for the standardization of routine manometric measurements, although shorter periods at possibly higher temperature could be used in the analytical control of plant operations.

B.O.D. of Industrial Wastes

Increasing attention is now being given to pollutional loads contributed by industry to publicly owned sewer systems. This trend calls for better methods of testing than have heretofore been available. Because of extreme differences in chemical composition and biological character, when individual wastes are analyzed for B.O.D. the results are often variable. The usual procedures involve seeding, buffering, dilution, and, in some instances, neutralization of inhibitory substances which are present. Variation in the details of any one of these

procedures may influence the result to a surprising degree.

Since for design and rate-making purposes the engineer requires information as to the pollutional load contributed by the waste after mixing with sewage, a logical approach to the problem consists in analyzing the sewage both in the presence and in the absence of the waste in question. For reasons which have already been discussed, *i.e.*, its wide range and its precision the manometric method is particularly well suited to tests of this kind. The authors have used it successfully with a number of food processing wastes. In this procedure the sewage-waste mixtures are prepared by diluting one volume of waste with 5 or more volumes of sewage. The B.O.D. of the waste is calculated by means of the following formula:

$$\text{B.O.D. of waste} = \frac{(\text{B.O.D. of mixture} \times 100) - (\text{B.O.D. of sewage} \times \text{per cent sewage})}{\text{per cent waste}}.$$

Use of Supplementary Inorganic Phosphate

In analyzing trade wastes, it was found desirable to add phosphate to the diluting sewage. It is well-known in enzymology that in the fermentation of sugars by yeast preparations the oxidation is more rapid and complete in the presence of added phosphate. The phosphate acts as a catalyst, and the two steps of the reaction are written as follows (11):

(1) $2C_6H_{12}O_6 + 2Na_2HPO_4 \rightarrow C_6H_{10}O_4(Na_2PO_4)_2 + 2H_2O + 2CO_2 + 2C_2H_5OH$

(2) $C_6H_{10}O_4(Na_2PO_4)_2 + 2H_2O \rightarrow C_6H_{12}O_6 + 2Na_2HPO_4.$

Normally, sewage contains sufficient phosphorous to permit the omission of this substance from the test; but in the testing of certain food processing wastes by the procedure described, it has been found necessary to add phosphate to the diluting sewage in an amount of approximately 10 ml. of tenth-normal monobasic phosphate per liter.

Measuring the Activity of Activated Sludge

The procedure described for the determination of the B.O.D. of industrial wastes suggests a procedure for estimating the activity of activated sludge and trickling filter slimes. The method is based on the principle that the oxygen demand of a mixture of active sludge and sewage is greater than the sum of the demands of the two constituents as determined separately. Wooldridge and Standfast have studied this problem, using Barcroft differential manometers. Their studies show that throughout a holding period of from 2 to 6 hours the oxygen demand of the mixtures bears a constant relationship to the total demand of the sewage and sludge when determined separately.

This field of investigation has not been pursued, but it is readily apparent that, in the control of sewage-oxidation processes, the proven manometric techniques which have been described should be of considerable value. When used in the manner suggested, the apparatus becomes essentially a miniature treatment plant in which the separate effects of many variables, such as sewage strength, sludge activity, sewage-sludge ratios, temperatures, etc., can be studied with a minimum of time and effort.

Summary and Conclusions

Various forms of manometric apparatus adapted for the estimation of sewage strength are described.

Experiments with the Warburg type of manometer indicate that these methods possess several advantages over the

standard dilution method of estimating B.O.D. It has been shown that, using undiluted samples with constant aeration and mixing, the rate of oxidation is greatly increased. The 24-hr. values at 25° C. are approximately 75 per cent of the standard 5-day values. For plant control purposes shorter incubation periods are possible.

The Warburg method is recommended for use in routine examination of sewages and trade wastes and in the control of sewage treatment processes. It is especially recommended for sewage research studies because of the relative ease and precision with which the several variables can be controlled.

Present commercial equipment, designed for making 6 to 13 parallel determinations, is expensive and is also too fragile for use by untrained analysts; but experiments are now in progress with simplified apparatus which it is hoped will remove these objections.

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B.O.D. DILUTION TECHNIQUE

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Because of the diversified nature of the sewage and trade waste samples analyzed in a state laboratory, it is necessary to prepare a large number of B.O.D. dilutions of each sample in order to be assured of covering the proper range. Any steps that economize on time without sacrificing accuracy are worth consideration.

The Ohio Department of Health Laboratory has adopted the following procedures which have been found to be of great assistance in preparing a large number of dilutions in a short time. For dilutions of over 1 per cent, a series of special pipettes were prepared (by a commercial glass-blower) and calibrated in the laboratory so that any desired dilution can be made with only one pipette full of sewage and without any calculations.

The B.O.D. bottles used were all of the same type and were found, by actual calibration, to contain from 300 to 310 ml. The bottles were marked, or etched, with an electric marker, with the numbers 0 to 10, corresponding to the number of ml. over 300, the bottle would contain.

The special pipettes that were prepared are indicated by the following table:

Pipette "Number" (%)	Volume Range Calibrated (ml.)	Stem Markings
50	150.0 to 155.0	"0" @ 150.0, "1" @ 150.5, etc.
33⅓	100.0 to 103.3	"0" @ 100.0, "1" @ 100.3, etc.
25	75.0 to 77.5	"0" @ 75.0, "1" @ 75.2, etc.
15	45.0 to 46.5	"0" @ 45.0, "1" @ 45.15, etc.
10	30.0 to 31.0	"0" @ 30.0, "1" @ 30.1, etc.
8⅓	25.0 to 25.8	"0" @ 25.0, "1" @ 25.1, etc.
5	15.0 to 15.5	"0" @ 15.0, "1" @ 15.05, etc.
3	9.0 to 9.3	"0" @ 9.0, "5" @ 9.15, "10" @ 9.3
1.8	5.4 to 5.6	"0" @ 5.4, "5" @ 5.5, "10" @ 5.6

Each pipette was calibrated by weighing, marks being made on a narrow strip of graph paper previously mounted on the stem with label varnish. After the calibration was completed, the graph paper was protected by two layers of label varnish.

In preparing dilutions above 1 per cent by this means, the B.O.D. bottle is filled about 1/3 full of dilution water; then the pipette marked with the desired percentage is selected from the rack and filled with well-mixed sewage to the number which corresponds to the number etched on that particular B.O.D. bottle. After transferring the sewage to the B.O.D. bottle, the bottle is then filled with dilution water, stoppered, and the contents mixed by inverting. Thus, only one pipetting operation is necessary, resulting in better accuracy as well as economy of time.

For preparing dilutions of 1 per cent and under, a special apparatus (see sketch) has been assembled in order to simplify the operations. The first step in calibration was to determine the total volume contained from mark "a" (zero mark on burette) to "d" (the tip of the burette). In so doing, it is necessary to have the stirring rod in place, in order to compen-

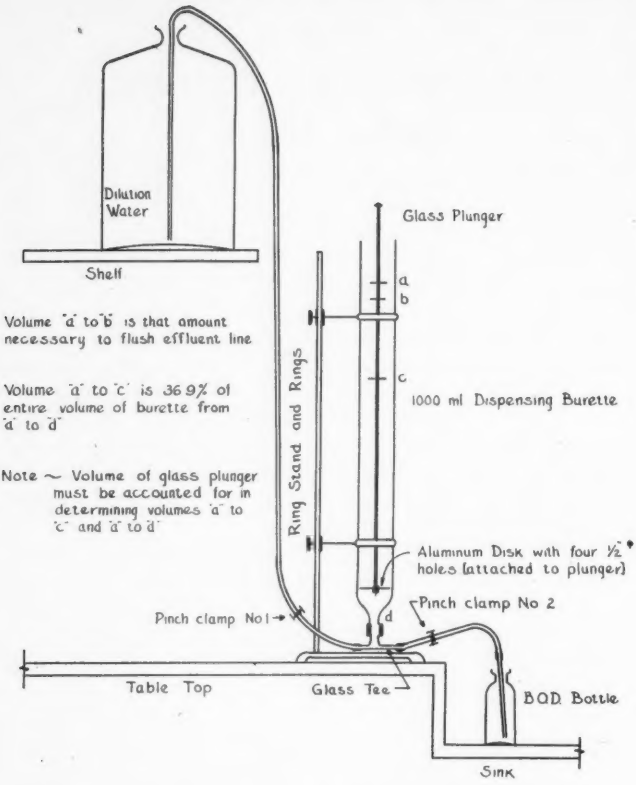
Dilution Water
Shelf
Volume "a" to "b" is that amount necessary to flush effluent line
Volume "a" to "c" is 36.9% of entire volume of burette from "a" to "d"
Note ~ Volume of glass plunger must be accounted for in determining volumes "a" to "c" and "a" to "d"
Glass Plunger
a
b
c
1000 ml Dispensing Burette
Ring Stand and Rings
Aluminum Disk with four ½" holes (attached to plunger)
Pinch clamp No 2
Pinch clamp No 1
d
Table Top
Glass Tee
BOD Bottle
Sink

FIGURE 1.—Apparatus for preparation of B.O.D. dilutions of 1 per cent and less.

sate for its volume. The second step was to withdraw 36.9 per cent of this volume and place a mark ("c") at the level. Next the volume necessary to flush out the effluent line was determined, and mark "b" placed on the burette to show this amount. The last step was to prepare a special pipette to deliver exactly 1.00 per cent of the total volume of the burette ("a" to "d"). In the particular apparatus prepared the total volume "a" to "d" was found to be 1,090 ml., and a mark was placed at "c" so that the volume withdrawn from "a" to "c" is 36.9 per cent of 1,090 (402.2 ml.). The volume "a" to "d" was about 40 ml., or more than enough to flush out the line. The special pipette was calibrated to deliver 10.9 ml. of sewage.

The reason for selecting 36.9 per cent was to choose some percentage which would give a series of dilutions so that at least two would show a 30 to 70 per cent depletion of dissolved oxygen. It was desired to have the next lower dilution more than 50 per cent as strong as the preceding one in order to get a better overlap. Also, this figure gives a series which can be repeated in cycles of 5 with a shift of the decimal point. The following table illustrates the convenience of using this series:

Original Strength (%)	Drain to	Fill to	New Dilution Strength (%)
1.00	63.1% (Mark "c")	Top (Mark "a")	0.631
0.631	63.1% (Mark "c")	Top (Mark "a")	0.398
0.398	63.1% (Mark "c")	Top (Mark "a")	0.251
0.251	63.1% (Mark "c")	Top (Mark "a")	0.1585
0.1585	63.1% (Mark "c")	Top (Mark "a")	0.100
0.100	63.1% (Mark "c")	Top (Mark "a")	0.0631
0.0631	63.1% (Mark "c")	Top (Mark "a")	0.0398
0.0398	63.1% (Mark "c")	Top (Mark "a")	0.0251
0.0251	63.1% (Mark "c")	Top (Mark "a")	0.01585
0.01585	63.1% (Mark "c")	Top (Mark "a")	0.0100
0.0100	63.1% (Mark "c")	Top (Mark "a")	0.0063

For calculation, the percentage figures are usually rounded off to 1.0, 0.63, 0.40, 0.25, 0.16, 0.10, etc.

The procedure followed for dilutions of 1 per cent and under basically is as follows:

I.—(A) Flush out apparatus, fill cylinder about ½ full with dilution water, close clamp No. 1.

(B) Add 1.00 per cent of well-mixed sewage with special pipette, then open clamp No. 2 until level "a" is exactly reached; close clamp No. 1.

(C) Mix thoroughly by pulling plunger disk from bottom to within 2 or 3 in. of top, then back down. Repeat this operation 2 or 3 times or as often as necessary for complete mixing. Avoid entrapping air bubbles in the mixing process.

(D) Flush effluent line by opening clamp No. 2 and draining to level "b." Close clamp No. 2.

(E) Insert glass tube into B.O.D. bottle, and open clamp No. 2. Drain carefully to mark "c" and close clamp No. 2.

(F) Remove glass tube from B.O.D. bottle and insert glass stopper into bottle. (This is the 1 per cent dilution.)

II.—(A) Open clamp No. 1, fill to mark "a" and close clamp No. 1.

(B) Mix by raising and lowering plunger 3 times.

(C) Flush by opening clamp No. 2, draining to mark "b", and closing clamp No. 2.

(D) Fill next B.O.D. bottle, draining down to level "c" and closing clamp No. 2.

(E) Remove bottle (0.63 per cent dilution) and insert stopper.

III.— Repeat steps II (A) through (E) for 0.40 per cent dilution.

IV.— Repeat as often as necessary to reach last dilution desired.

By using this procedure an entire series, starting with 1 per cent can be set up in a very short time and with good accuracy. The most important precautions are to watch the levels "a" and "c" very closely, closing the pinch clamps at the proper moment.

POWER EFFICIENCY IN ACTIVATED SLUDGE AERATION

By Richard Pomeroy

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Attempts to compare the efficiency of different methods of aeration in activated sludge plants have frequently been made on the basis of plant performance. The efficiency of a plant in purifying sewage, however, is dependent upon several variables other than the efficiency of aeration. It would be much better to compare aeration systems on the basis of the quantity of oxygen dissolved under specific conditions. There is a scarcity of published information of this sort.

Presented here are the results of tests made at the activated sludge plant of the city of Laguna Beach, California. It is to be hoped that more data of this nature will become available in literature in the years ahead so that the efficiency of different systems can be more reliably compared, and so that specifications and guarantees of performance can be made in terms of such efficiency.

The activated sludge plant at Laguna Beach as originally constructed had two aeration tanks, each equipped with an aerator operating on the venturi throat principle. A pump drew water down through the submerged throat, where air was also sucked in, and the mixture of air and water was forced to the bottom of the tank. The aerators, as installed, did not dissolve enough oxygen for satisfactory plant operation. The operator, Mr. R. D. Woodward, redesigned the throats, providing larger water and air passages, and made other appropriate changes, and was then able to make the plant operate successfully.

Test Procedure

Determinations of aeration efficiency were made both before and after the remodeling of the aerators. These efficiency tests were carried out as follows: A tank to be tested was filled with clean city water. A solution of sodium bisulfite was added in slight excess over the amount of dissolved oxygen in the water. (1 lb. of dissolved oxygen requires 6.43 lb. of $NaHSO_3$). The water in the tank was then thoroughly mixed by operating the aerator pump but with the air shut off. It was then allowed to stand for approximately 2 hours during which time most of the oxygen was used up. The pump was again started and chlorine or hypochlorite solution was added until the excess sulfite was just neutralized. Due to the agitation some oxygen was dissolved so that concentrations of 1.5 to 3.5 p.p.m. were present. The aerator was then started and samples for dissolved oxygen determination were taken at measured intervals of time, alternate samples being taken at opposite ends of the tank.

The observed concentration of dissolved oxygen should be in accord with an equation of the form:

$$\text{D.O.} = (\text{D.O.})_o + [(\text{D.O.})_{max} - (\text{D.O.})_o] \ (1\text{–}10^{-Kt})$$

"D.O." refers to dissolved oxygen, while the subscripts "*o*" and "*max*" refer to the initial D.O. and the ultimate saturation value. This latter value is not the normal solubility of oxygen, for the pressure on the sub-

merged bubbles causes an increase above the saturation at atmospheric pressure. K is a rate constant and t is the time in minutes.

In all tests which have been made, the experimental data have been found to fit closely the theoretical equation. The necessary constants may be derived by the same procedures used to fit B.O.D. data to the first-order curve, since this is also a first-order rate equation.

In order to compare different aeration systems it is necessary to specify standard test conditions. It is most logical that the results should be expressed in terms of the rate of solution at zero dissolved oxygen and at a temperature of 20° C. The rate of solution at the temperature of the test and at zero dissolved oxygen in parts per million per minute would be equivalent to $2.303 \times (\text{D.O.})_{max} \times K$. To correct the result to a temperature of 20° C. it may be assumed that $(\text{D.O.})_{max}$ is proportional to the solubility of dissolved oxygen, while K may be assumed to be inversely proportional to the viscosity of water. In the neighborhood of 20° C., the solubility of oxygen decreases 2.01 per cent per degree, and the viscosity of water decreases 2.45 per cent per degree. Hence the rate of solution at zero concentration may be presumed to increase 0.44 per cent per degree. This correction can be applied with negligible errors over the range from 15° to 25°.

The results of tests in two aerators at Laguna Beach made on May 12, 1941, gave results as shown in Table I.

It is interesting to note that satisfactory operation was obtained in these tanks with aeration capacity sufficient to dissolve 19 p.p.m. of oxygen per hour at zero concentration. The actual rate of oxygen dissolved in normal operation is, of course, less than this, since some oxygen is present in the water. From observations on other activated sludge plants it is the opinion of the authors that for Southern California conditions, this represents the aeration capacity which should be provided if satisfactory treatment is expected. It is possible, however, that with higher aeration rates good purification could be attained with higher sludge concentrations and shorter aeration times.

TABLE I.—Aeration Tests at Laguna Beach, Calif., May 12, 1941

	Tank 1	Tank 2
Number of oxygen determinations	14	10
$(\text{D.O.})_{max}$	9.96	10.06
K	0.0136	0.0146
Average difference between calculated and experimental results (p.p.m.)	0.05	0.06
Rate of solution at zero D.O. (p.p.m. per hour)	18.7	20.3
Temperature (deg. C.)	20.3	20.8
Calc. rate at 20° C. (p.p.m. per hour)	18.7	20.2
Capacity of tank (lb.)	390,000	390,000
Rate of solution (lb. per hr. at 20° C.)	7.29	7.88
Kilowatts used	4.92	4.92
Pounds per kilowatt hour	1.50	1.60

The efficiency of an aeration system is best measured by the pounds of oxygen dissolved per kilowatt hour. The last line of the table shows an average of 1.55 lb. or 704 grams of oxygen per kilowatt hour input to the motors.

When Mr. Woodward began his redesigning of the aerators the rate of solution of oxygen was only 4.8 p.p.m. per hour and the power consumption per tank was 6.3 kilowatts. After reconstruction the efficiency was five times as great.

A CRITICAL REVIEW OF THE LITERATURE OF 1947 ON SEWAGE AND WASTE TREATMENT AND STREAM POLLUTION

By W. Rudolfs, *Chairman*, H. E. Babbitt, D. E. Bloodgood, G. P. Edwards, H. A. Faber, A. L. Genter, H. Heukelekian, R. P. Logan, H. J. Miles, F. W. Mohlman, C. C. Ruchhoft, C. N. Sawyer, L. R. Setter, L. W. Van Kleeck

Committee on Research, Section A, Federation of Sewage Works Associations

In presenting its sixteenth annual review of the literature, the Research Committee aims to follow the pattern of previous years. The review is intended (1) to portray the progress made from year to year, (2) to provide an evaluation of the contributions made, (3) to call attention to published material that is not readily accessible, and (4) to provide a comprehensive bibliography for convenient reference. The stimulation of further research and the coordination of current studies are further objectives.

An intriguing concept of the relation between polluted water and poliomyelitis was advanced during the year. The statement that certain forms of cyanides produce symptoms and pathological lesions similar to poliomyelitis, and that the cyanides may engender the production within the body of an endogenous virus which would leave the body instead of entering it, is rather beyond the scope of this review for comment, but certainly of interest to all if the concept were to be substantiated. Certainly far more information is required to explain the observed facts that polluted waters, even in the absence of living organisms, may have severe physiological effects. Recent research has indicated that certain pyrogenic products, when introduced in minute quantities into the bloodstream, may cause difficulties. "Pyrogens"—defined as agents which cause a rise in temperature—are probably complex bodies engendered by certain types of microscopic organisms, or possibly they are products of bacterial metabolism which are not destroyed by ordinary sterilizing procedures and withstand temperatures over 450° F. Whether or not pollution increases the pyrogen content of the water, and whether or not these products in relatively high concentrations may be of importance when present in drinking water, is not known, but they are of interest to the research worker in relation to the observed physiological effects after heavily polluted surface waters are treated and chlorinated.

Byproduct recovery from sewage treatment is usually considered to include only utilization of sewage sludge for fertilizer and gas production. Another form of salvage concerns itself with the use of sewage effluents in agriculture or for industrial purposes, such as for cooling or quenching waters. There are a number of places in this country where sewage effluents are used in industry, but such effluents are the result of certain established types of sewage treatment, they are incidental, and they do not reduce the pollution load. Of particular interest, therefore, is a new process of flax retting, where the treatment was changed from anaerobic to aerobic digestion in order to utilize the water and at the same time reduce the pollution load. This example is stimulating, because it indicates that certain old and well-established industrial processes may be changed and modified to produce less polluting matter and to reduce stream pollution without specific treatment

devices. Other industries have accomplished similar results, but the examples are far too few to let this one pass without mention.

During the last few years the impression has been prevalent that no material advance can be expected in sludge digestion until more basic information is available concerning the mechanism of digestion. There is evidence that more intense studies are being made.

Although chemical and mechanical treatment of sewage appears to be fairly stabilized in this country, considerable interest is evidenced in England as indicated by several published papers.

Again this year no outstanding contribution was published on plain sedimentation, although a few papers were made available on operation and operation difficulties.

There were again some papers on analytical procedures and methods, but by no means as many as the subject requires. It is hoped that within the next few years the work set in motion by the Federation in 1947 may bear fruit.

Several papers dealing with the mechanics of the activated sludge process were published. This was a material improvement over the last two years. The majority of the papers were concerned with operation, including greater flexibility, sludge concentration and air diffusion.

Chlorination of sewage and sewage effluents received attention, both from research and operation standpoints. The work reported from Johannesburg, pertaining to complete bacterial sterility, is easily the most important.

Studies on sludge disposal were primarily concerned with operation results. Heat treatment and covered drying beds were the subject of several papers, as well as sludge production for fertilizer.

Papers of greatest interest on biological filters pertained to the control of filter flies. Application of DDT or gammexane aided in the control of flies and had no effect on purification, but the effluents may be toxic to fish. There were more papers on industrial waste than any year since the review has been published. National and local organizations showed great interest in the problem by scheduling a considerable number of papers. Interest of industries has increased materially. Papers on paper and pulp wastes increased considerably, and other papers on pickling liquors, food wastes, petroleum and plating wastes were among the references cited.

Considerable material was published on stream pollution. The number of papers on biology and chemistry was still small, and those pertaining to measurement and expression of results were of more than passing interest, because they seem to indicate a change in the prevailing conception of stream pollution phenomena.

This annual review is not presented as a complete enumeration of all papers published during the past year, but is believed to include those of greatest importance and significance.

General

Sewage and Disease

The conquest of water-borne diseases can be read in the statistics covering a period of the past 8 years, during which time 316 outbreaks with 114,000 cases of sickness and 84 deaths caused by impure water were recorded (16).

Discussion of the incidence of poliomyelitis virus in sewage continues. Melnick (199) published the results of tests with Chicago sewage during the 1943 epidemic and of monthly tests with New York City sewage for a period of 6 years (1940–45). Of 61 tests with Chicago sewage during the peak of the epidemic, 6 were positive; after the epidemic none out of 21 samples was positive. Imhoff tank sludge did not give positive results. Sewage sam-

ples from hospitals treating poliomyelitis patients were all negative.

In 2 out of 6 years no positive tests were obtained from the New York City sewage samples, in spite of the fact that in one of these years there was a considerable number of poliomyelitis cases on the sewer line sampled. All the positive tests were obtained in the late summer and fall when the number of cases was at a maximum. Calculations show that in Chicago 6 million monkey infectious doses of virus were leaving the sewage disposal plant per minute; in New York this value was 500,000 doses. It was suggested on this basis that approximately 6 per cent of the people in Manhattan may have been carriers of the poliomyelitis virus.

An entirely new concept of the etiology of poliomyelitis was advanced by Scobey (246) (247) (248). The author (246) points to the incidence of severe epidemics of poliomyelitis during years of severe drought, as in 1930 and 1946, and the periodicity of 15 years for both phenomena. The prevalence of disease is also greater during the dry season of a given year. Scobey suggests that cyanides can cause gastro-intestinal disturbances and neurological symptoms identical with those of poliomyelitis. Under conditions of drought and consequent high cyanide content, gastro-intestinal disturbances and poliomyelitis would not be separate entities but conditions arising from the same source. The origin of cyanides in water are as follows: (*a*) cyanophore glucosides from vegetable mater, (*b*) sulfocyanates in animal excretions, and (*c*) putrefaction of animal tissues. Cyanides produced from these sources may be washed from the soil into ground or surface waters and may be augmented by cyanides produced from the same sources in surface waters.

In addition to water, foods which are harvested in advance of their natural maturity contain more glucosides capable of producing hydrocyanic acid than those permitted to reach a natural maturity.

In further elaboration of this concept the author (247) points out that hydrocyanic acid is capable of producing symptoms and pathological lesions identical to those of poliomyelitis. Thus the cyanides may engender the production within the body of an endogenous virus which would leave the body instead of entering it. As a further possibility it is suggested that the virus may be a cyanolytic enzyme capable of producing or accelerating the production of hydrocyanic acid. Analogous effects of heat and oxidizing agents on both poliomyelitis virus and cyanides are called to attention. Other analogies as to functional disturbance of the thyroid gland and susceptibility to poliomyelitis and cyanides alike are pointed out.

Other indirect evidence is advanced by the same author (248), namely, the analogy between paralytic shellfish disease and poliomyelitis. The chain of events in paralytic shellfish disease according to the author is as follows: Cyanides derived from decomposition products of vegetables and animal matter originating either in the soil or in water are assimilated by plankton, which in turn are consumed by shellfish such as mussels, and finally by man, causing an acute poisoning with profound action on the nervous system and with symptoms similar to poliomyelitis. The seasonal and geographic incidence of the two diseases are also similar. The author again contends that the same etiological factor (hydrocyanic acid) is responsible for these two diseases. The adsorption of the hydrocyanic acid through the skin is also considered possible, with the possible contraction of poliomyelitis by bathing at certain times and locations where the waters are polluted with enough cyanides.

Experimental work by Stokes, Jones, Mohun and Miles (259) was carried on to determine the effect of drying and

digestion of sludge on some pathogenic organisms, which were added artificially in large numbers. The organisms studied were *Bact. paratyphosum* and *Bact. typhi murium*. Difficulties were encountered as usual in counting the organisms, due to the interference by the large numbers of nonpathogenic organisms present in the sludges. In the artificially infected sludge dried on conventional beds *Bact. paratyphosum* could not be recovered after 27 days but *Bact. typhi murium* could be recovered after 180 days. The latter organism could be isolated after 45 days of anaerobic digestion. Out of 33 samples of partially digested sludge examined from different sewage plants, three of which were obtained from districts in which typhoid epidemics had occurred, no pathogenic bacteria of the typhoid, dysentery or salmonella group could be isolated.

Maxey (194) concluded that the hazard created by disposal of untreated fecal wastes on the roadbed of railroads is of a low order, because the longevity of the pathogenic bacteria, under natural conditions of sunlight and drying prevailing on the surface of the roadbed, is but a few hours. Furthermore, the number of persons exposed to contact is very small. The author does not attach much importance to the hazard arising from dust particles and fine droplets carried away in the air over the roadbed. The chance of contamination reaching drinking water supplies through discharge of fecal wastes from conveyances en route exists, but it is argued that the present day tendency is not reliance on safe water at the source but rather on efficient treatment. He reasons, therefore, that the public health menace from this source would be insignificant.

Toxicity

Kalabina *et al.* (162) studied the effect of toxic substances of nonferrous metalurgy on the microorganisms and biochemical processes. They found that 0.5 p.p.m. of copper sulfate as copper was toxic to all microorganisms and 0.1 p.p.m. was toxic only to bacteria. Lead in 0.1 p.p.m. concentration was toxic to biochemical oxidations, 0.5 p.p.m. to flagellates and infusoria, 0.5 p.p.m. to 1.0 p.p.m. nitrifying bacteria and 1 p.p.m. to other bacteria. Holm (147) considered *Daphnia magna* as a good indicator of toxicity of wastes. Menick (199) reported on the effect of chromium-containing waters on plants and lower organisms.

Sulfur and Iron Oxidizing Bacteria

Parker (209), in a further investigation of the mechanism of corrosion of concrete and the organisms responsible for it, attempted to fill in the gaps left by this previous work. It had been found previously that *Thiobacillus concretivorus* is the organism responsible for the oxidation of sulfur to sulfuric acid with consequent corrosion of concrete. But this organism could not exist at pH values higher than 6.5 while the value of new uncorroded concrete is 11 to 12. Furthermore this organism cannot utilize hydrogen sulfide, which is a product formed by the reduction of sulfate in sewers. A number of other sulfur organisms were isolated from the corroded concrete. One of these organisms, *Thiobacillus thioparus*, can oxidize among other sulfur compounds, elemental sulfur to sulfuric acid at a pH range of 3.5 to 8.5. Another group of miscellaneous species could oxidize thiosulfates to polythionates and sulfate without the formation of elemental sulfur. This organism also can exist over a wide range of pH (2.0 to 10.5). The latter group exists in the initial stage of corrosion at pH 9 to 11, the former group in the intermediate stages (pH 4.5 to 9), and *Th. concretivorus* in the final stages below pH 6.0. On fresh concrete exposed to hydrogen sulfide in the sewer atmosphere, chemical changes take place first, involving carbonation (which lowers the

pH value to 8.4) and the fixation of hydrogen sulfide as sulfuric and polythionic acids. These compounds are oxidized by the miscellaneous group. *Th. thioparus* then becomes active, converting the thiosulfates and polythionates to sulfur and sulfuric acid and lowering the pH value. Finally *Th. concretivorus* becomes active in the acid range, oxidizing the surfur to sulfuric acid and lowering the pH value still further. Thus, while the primary corrosive agent is hydrogen sulfide, none of the bacteria can utilize it. Corrosion proceeds instead by the intermediate production of sulfates, polythionates and sulfur by chemical means.

The oxidation of ferrous sulfate to ferric sulfate in acid mine drainage is attributed to bacteria by Colmer and Hinkle (71). The subsequent hydrolysis of the ferric sulfate to hydroxide imparts the rusty color to mine drainage water. By the addition of disinfectants and bacteriostatic agents the oxidation and the production of rusty color were prevented even when exposed to air. A bacterium was isolated which was able to bring about the rapid oxidation of ferrous to ferric iron. Another bacterium isolated from acid mine water was able to oxidize sulfur to sulfuric acid, and had morphological and physiological properties of *Thiobacillus thiooxidans*. This organism can exist under environmental conditions prevailing in the mines and can oxidize the sulfur existing in coal to sulfuric acid, giving rise to high acidities in the drainage water.

Miscellaneous

Buswell (61) calls attention to the fact that in determining the oxygen equivalent of sodium nitrate for the stabilization of organic matter, the nature of the reactions should be better understood. The quantity of oxygen made available from the reduction of nitrate will depend upon whether the nitrate is reduced to nitrogen gas or ammonia, on whether the reaction stops at the nitrite stage. Since all of these reactions are possible, it is best to know what the products of the reaction are and determine the oxygen made available from the quantities of reduced nitrogen compounds formed and the residual quantity of nitrogen.

Keefer (165) has determined the ammonia-removing capacity of a number of different types of sludges after drying, and in some cases after igniting, to reduce the volatile matter contents to various percentages. Settled and filtered sewage was passed through the prepared sludges and the removal was determined. After the material was no longer capable of removing ammonia the sludge was regenerated with sodium chloride. The results indicate that sodium chloride treatment, after the rate of adsorption of ammonia had decreased, restored the adsorbing capacity. For a given sludge the artificial change of volatile matter content by partial ignition from 52 per cent down to 10 per cent did not materially affect the adsorption capacity, but upon complete ignition the capacity was equally reduced in raw, digested, and activated sludges. Of the non-ignited sludges, raw sludge was the most effective in removing ammonia; digested sludge gave the next best results, and activated sludge was the least effective.

Activated sludge removed 100 to 125 mg. of ammonia per 1,000 grams of solids. It was concluded that the removal of ammonia by activated sludge is due to causes other than base-exchange reaction.

Analytical Procedures

The ninth edition of *Standard Methods* (37) came off the press during the year. The more important revisions in sewage and sludge methods over the eighth edition are as follows:

1. The determination of albuminoid nitrogen was dropped.
2. The Alsterberg or sodium azide

modification of the Winkler method for dissolved oxygen is recommended for samples containing appreciable quantities of nitrites.

3. The preflocculation with alum of samples containing high sediment was recommended in the Winkler or Modified Winkler dissolved oxygen tests.

4. A fortified phosphate dilution water for the B.O.D. test replaces the bicarbonate dilution water.

5. The rapid aluminum dish estimate of total suspended solids has been transferred from the nonstandard section to a standard test.

6. In the Gooch method of suspended solids determination the asbestos mat has been doubled in thickness and the 103° C. drying period has been reduced from 2½ hours to 1 hour.

7. The glass electrode pH meter is recommended for sewage and sludge on a par with the colorimetric method.

8. The antimony colorimetric method for sulfides has been replaced by the methylene blue test. The preferred titration method for sulfides has been retained with no significant change.

9. The eighth edition did not specify a standard technique for grease determination in sewage and sludge. The ninth edition defines grease as that material which is extracted from an acidified sample by petroleum ether. The procedure for sewage consists of partial separation by acidification, boiling, chilling, and filtering. The filtered matter is dried at 103° C. and extracted in a Soxhlet extractor to which has been added the petrolic ether used in the wet extraction of the filtrate. Grease in liquid sludge is similarly determined on a smaller sample volume.

10 A nonspecific method for the weight of settleable solids with a detailed nonstandard procedure in the eighth edition has been replaced by a standard difference method in the new edition. The difference method consists of determining the total suspended solids before and after settling. In view of the known large errors in the measurement of the total suspended solids in unsettled sewage, some may question the advisability of incorporating this difference method in *Standard Methods*.

11. The nonstandard procedure for the B.O.D. of chlorinated sewage has been placed in the standard section.

12. New tests appear in the nonstandard section. These include volatile acids in digesting sludge, oxygen demand and activity of activated sludge, two grease tests, a colorimetric method of determining pH of sludges by testing the dialyzate, and a modified test of organic carbon in sewage.

Ellis *et al.* (93) have prepared a manual on water quality for the aquatic biologist. Many of the tests and techniques of *Standard Methods* are slightly modified for field use. Industrial waste pollution has raised a need for special tests which are useful to the aquatic biologist; these have been compiled and their significance noted.

A number of papers have appeared dealing with the limitations of the B.O.D. dilution test and direct oxygen utilization tests. To nullify the effect of nitrification in the B.O.D. test of oxidized effluents and stream samples, Hurwitz *et al.* (153) studied Sawyer's (239) pasteurization and seeding method and a new acidification, neutralization, and seeding method. The latter was considered equally effective, simpler, and could be used as a preservative for B.O.D. samples in the field. The samples were acidified to pH 3.0 to 2.0 and after a reaction period of 15 minutes or more the pH was readjusted to 7.0 to 7.4 and dilutions with standard seeded dilution water were prepared. The acid treatment appears effective in eliminating nitrifying organisms.

Gehm (106) reported the course of biological oxidation of paper and pulp mill wastes with various B.O.D. dilu-

tion waters. The B.O.D. test is subject to further refinement as knowledge is gained of seeding, nitrification and deficiency of certain growth elements. Until the limitations of the test are determined, Weston, discussing Gehm's paper (106), recommends both B.O.D. and C.O.D. tests on industrial wastes.

The use of the B.O.D. test in connection with brewery wastes is discussed by Mason, *et al.* (193).

The effects of 27 inorganic and organic substances such as are found in the petroleum and metal plating industries were determined on the dissolved oxygen and B.O.D. tests by Heukelekian (140).

In the direct oxygen utilization test Falk and Rudolfs (98) found that by shaking the sample every 5 minutes the all-glass Sierp apparatus using gaseous oxygen gave results comparable to the B.O.D. by the dilution method for sewage and some industrial wastes.

Heukelekian (141) discussed the limitations of the B.O.D. dilution test and presented data to show that for research on industrial wastes the direct oxygen method permits the study of oxidation rates at any desired concentration.

A chemical method was employed by Winkler and Wipf (291) to measure the amount of flow in a river at progressive points by adding a known volume and concentration of chemical, such as NaCl, and titrating samples of admixture in the unknown flow with 0.01 N $AgNO_3$ to determine the dilution factor. Another method which gave good results was the use of a solution of about 2 mg. $NaNO_2$ per liter of water used for infecting the unknown flow and a colorimetric nitrite test on the total flow at frequent intervals.

Kirn reported (169) on a stream sampler designed to hold two 250-ml. and one 1,000-ml. bottles. An advantage would be gained by lowering the exhaust air port of the bacteriological sample compartment so that the neck of the bottle would always be above the compartment water level.

Gray and Moses (116) report a high degree of accuracy in the use of an automatic residual chlorine recorder (for water) based on the photo-electric measurement of the yellow color produced by o-tolidine in acid solutions.

Taras (264) reports the preparation of two pH indicators for the determination of total alkalinity. One exhibits a color change from pale purple (pH = 5.0) to blue with a violet tinge (pH = 4.0). The other changes from deep yellow to maximum muddiness in the same pH range. The first is particularly useful in yellow-colored solutions where the bluish-violet endpoint is reflected back as a deep green.

Stones (260) estimated small amounts as low as 0.05 p.p.m. of chromium by a colorimetric comparison of the magenta color formed with chromates reacting with diphenylcarbazide in acid solution. Pretreatment with sulfite followed by $KMnO_4$ in acid converted the chromium to the chromate state.

Crumpler (76) reports that in acid solution tetraethylenepentamine reacts with copper to form a copper-amine color complex that follows Beer's law for the determination of copper over a wide range of concentrations.

In the determination of dissolved oxygen Wilcox (286) found that in using the amidol method of Isaacs and Gilcreas it was necessary to add potassium dichromate to compensate for the yellow color developed. This color was found to be due to the presence of nitrites. Ishimaru and Tikafusa (156) reduced a standard solution of $K_2Cr_2O_7$ with Zn-Hg amalgam and the resulting Cr^{++} was used to reduce the dissolved oxygen. The excess Cr^{++} is titrated with ferric alum. Air must be excluded, of course, in this procedure. Dean and Hawley (78) devised a field kit for the determination of dissolved oxygen employing an electrometric method for the determination of the endpoint in the usual Winkler pro-

cedure. With this same kit they could also determine chlorides within 0.06 gm. per liter up to concentrations of 25 gm. per liter of chlorides. A silver electrode was used to determine the endpoint. Another field method for the determination of dissolved oxygen was advocated by Koblyanskii (174) who adds Mohr's salt to the water under a layer of petroleum ether. Dimethylglyoxime is used to indicate the correct amount of salt to be added.

Schneebeli and Staut (243) found in the determination of chlorides in water that if 1 ml. of K_2CrO_4 (no concentration of K_2CrO_4 given) was added to 100 ml. of water followed by excess of $AgNO_3$, the red color developed could be compared to standards. In the extraction of the colored compound of phenol with 2,6,-dibromoquinonechlorimide, Basavilbaso (41) used isoamyl alcohol instead of butyl alcohol. He claims that a purer extraction can be obtained and that 2 gammas per liter of phenol can be determined and 1 gamma per liter estimated. Todd (267) uses an electrophometer instead of Nessler tubes in the determination of fluorides in water by Scott's modification of the Sanchis method.

In an attempt to correlate B.O.D. with oxygen consumed values, Rhame (226) used standard dichromate and sulfuric acid and evaporated to a small volume. The excess dichromate was determined iodometrically. Consistent correlation between the two methods was not obtained.

Haseltine (134) reviews several methods for the determination of cyanides and concluded that the Eldridge method gives the best approximation for cyanide wastes containing 5 to 10 p.p.m. The Friel-Wiest method can be used in presence of cyanates but its useful range is quite narrow.

Sedimentation

Hopkins (148) describes the use of transverse submerged baffles in the Montebello water filtration plant at Baltimore, Md. Although used for removing sediment from water, the idea might be adapted for use with sewage and industrial wastes. The sedimentation tanks are 320 ft. long, 230 ft. wide, 13.8 ft. water depth, and are partly divided by a central wall 240 ft. long to create around-the-end flow. Two vertical wooden baffles are installed transverse to the direction of flow, the first 230 ft. from the entrance and the second about 70 ft. from the free end of the central division wall in the outlet section. The baffles extend from the floor to within 4.5 ft. of the water surface, and are solid except for ports which are opened only when cleaning the tanks. The baffles are topped with a parabolic overflow section extending 2 ft. on each side. Sediment was deposited with greater uniformity after baffling, the first baffle being especially effective in obtaining increased deposition.

Herzik, Dabney, and Weiss (138) report performance data on two circular sedimentation tanks in Texas. Sewage is channeled along the circumference of the basin and downward by means of a circular metal skirt placed within the tank near the outside wall and extending from above the liquid surface to within a short distance of the bottom of the tank. The effluent is removed by means of a central notched circular weir trough with a diameter about one-half that of the tank. At Brownwood the tank serves as a primary clarifier, and with a theoretical detention period of 4.97 hours obtains 42.9 per cent removal of the 225 p.p.m. suspended solids in the influent. At Greens Bayou the tank serves as a final clarifier following a single stage high-rate filter, and with a theoretical detention period of 2.73 hours obtains 32.4 per cent removal of the 62 p.p.m. suspended solids in the tank influent.

Hart (133), discussing the design of gravity type oil-water separators for removing oil from industrial waste

waters, states that laminar flow should be approximated. The factors important in producing laminar flow are the optimum cross section of the tank and the critical velocity of the fluid.

When ground garbage is present in sewage, the solids and B.O.D. are removed by primary sedimentation as readily as are similar constituents from sewage without added garbage, according to Tolman (268). To insure no more solids and B.O.D. passing to secondary processes than would be the case without the added garbage, it will be necessary to provide some additional detention time in the primary tanks.

Chemical and Mechanical Treatment

An increasing tendency to regard chemical treatment as an aid or supplement to secondary treatment is evident in the recent literature.

Hurley (152), in writing on the use of chemicals in sewage treatment in Britain, says that chemicals as an aid to sedimentation are not widely used except where the chemicals are used for specific purposes, such as an auxiliary in overloaded plants or to cope with abnormal conditions encountered when certain industrial wastes are treated with sewage. In Yorkshire, sulfuric acid is used to "crack" the mixed sewage so that the grease from the wool factories can be removed and eventually recovered. Hurley also reports that he has performed a full scale experiment using the mechanical flocculation process. He considers it advisable to investigate this process quite extensively.

In Halifax, England, the sewage contains trade effluents that are of a greasy and soapy nature. Lumb, *et al.* (190) report that it has been necessary to pretreat the municipal sewage before the biological processes are attempted. For many years sulfuric acid has been employed in conjunction with grease recovery. At times the sulfuric acid has been supplemented by alumino ferric when the economics of the combination have been favorable. Laboratory experiments using chlorinated copperas indicated that 122 p.p.m. of Fe were required to obtain optimum removal. The best coagulation was obtained in the pH range 4 to 5. Other experiments were carried out obtaining comparisons between ferric chloride, ferric sulfate, and chlorinated copperas. The use of lime and chlorinated copperas proved too costly.

At the Bradford Corporation's Esholt Works (45) the sewage is comprised of equal amounts of domestic sewage and wastes largely from the wool scouring industry. The mixture of the two contains 800 p.p.m. grease (29). Treatment is by addition of sulfuric acid to pH 3.5, followed by sedimentation and trickling filters. It was not found economical to raise the pH after "cracking." An anticipated difficulty is the treatment of mixed sewage and wool scouring wastes when synthetic detergents are used for wool scouring. Experimental results show that an oxygen-absorbed reduction of only 25 per cent is obtained when a 1 to 9 mixture of such scouring wastes and domestic sewage is acid treated. A similar mixture of conventional wool scouring wastes containing soap and sewage shows a 62 per cent oxygen-absorbed reduction under similar treatment.

Goldethorpe and Nixon (112) describe work with Huddersfield sewage containing equal parts of domestic sewage, woolen trade wastes and chemical trade wastes, the bulk of the latter being separately sewered. The sewage and textile wastes are precipitated with acid, followed by settling and neutralization. They are then combined with the separately settled chemical wastes and treated biologically.

In this country a similar appraisal of the value of chemical treatment as an adjunct to secondary treatment is evident. Crist (75) describes a new plant designed to treat the mixture of domestic sewage of 3,500 persons and

1.3 m.g.d. of waste from grape, vegetable, and poultry processing. The combined sewage has a population equivalent of 16,500 persons. Primary treatment will consist of lime and copperas addition for pH control and to improve primary settling. Secondary treatment will consist of two high-rate filters and sedimentation. Separate sludge digestion is included. The primary treatment is designed to produce a 50 per cent reduction of B.O.D. and suspended solids.

A new 5 m.g.d. plant at Riverside, Calif., is described (157). It includes facilities for chemical precipitation, primary and secondary clarification, two-stage sludge digestion and chlorination. Ferric chloride will be used for coagulation and the dosage will be automatically proportioned to flow.

At Ridgewood, N. J. (14), the pretreatment of sewage with alum has been discontinued, but there has been some research on certain phases of chemical usage in sewage plant operation.

That chemical shortages have produced an increasing concern with the possibility of manufacturing coagulants at the treatment plant is evident from the literature. At the new Riverside, Calif., plant (157) ferric chloride for coagulation and ferrous chloride for odor control will be produced by passing chlorine solution over scrap bailing wire.

Ellis (92), in writing about the sewage treatment plant at Kingston-on-Thames, England, cites an experience during the war. When bauxite could not be obtained from France for the manufacture of aluminum sulfate, it became necessary to use the "red mud" of the aluminum industry, which consisted principally of iron oxide. About 2 tons of this substitute material was used each day to manufacture what proved to be a fair precipitant in the treatment of sewage. It became necessary to increase the degree of treatment, and to do this, crystalline ferrous sulfate, produced as a waste from the manufacture of titanium oxide, was chlorinated and used. The chlorinated copperas proved to be less expensive and more efficient than the "red mud."

The use of the autoxidation process for producing iron coagulants is described by Travaini (271). The process consists of blowing air and sulfur dioxide into tanks containing scrap iron and water. Sulfur dioxide and ferrous sulfate are simultaneously oxidized. A wide range of concentrations of ferrous sulfate, ferric sulfate, and sulfuric acid may be produced. Ferric sulfate is produced at a cost of $19.19 per ton and copperas at $9.58 per ton. These compare with delivered costs per ton of $40.50 for alum, $48.66 for ferric sulfate, $80 to $90 for ferric chloride, and $50 for copperas. The process is not recommended for small plants where skilled operators are not available.

Keyes (168) discusses the principles and advantages of the autoxidation process.

A new coagulant composition for sewage is described in a patent (235). Chlorides of various metals such as iron and aluminum are combined with proteins such as glue and gelatin to produce the coagulant. It is claimed that the average sewage requires from 4 to 8 p.p.m. of gelatin and 20 to 60 p.p.m. of ferric chloride. Iron requirements are reduced 20 to 50 per cent. A tougher floc is also claimed.

Several papers dealing with research on chemical treatment of sewage were published.

Hay (135) proposes a theory of chemical coagulation dealing primarily with water, but presumably applicable to sewage. The commonly accepted theory of coagulation by agglomeration is discussed and found wanting in the following respects:

(1) If true agglomeration occurs the observed rapid "break" with subsequent extreme clarity of liquid would not be expected.

(2) With gradual agglomeration a critical concentration of coagulant would not be expected.

The proposed protogel theory envisions the formation of a gel-like structure by the interlocking, either physically or by attractive forces, of the colloidal particles and coagulant. All foreign matter would be enmeshed in this so-called protogel. A subsequent shrinkage (syneresis) of the protogel would result in disintegration (the "break") and the formation of small flocs. Agglomeration would then result in larger flocs.

According to the concept, all of the liquid would have been contained within the protogel structure and would have had to pass through its pores.

Rudolfs (232), in his studies on coagulation of sewage, states that the soluble or colloidal sol, and not the coarse dispersed material, is mainly responsible for the coagulant demand. Urine present in sewage contains substances which absorb iron coagulants or interfere with the action of the coagulant. Additions of urine to sewage result in poorer clarification with iron salts and require increased dosages of iron. Studies made on the action of lime in clarification of sewage have brought to light some interesting phenomena. The action of lime in clarification of water and sewage has generally been attributed to the formation of calcium carbonate, on account of the neutralization of bicarbonates and carbonic acid with the lime. The Rudolfs tests indicate that 95 per cent of the turbidity in sewage is removed before appreciable calcium is precipitated from solution. The phosphates normally present in sewage have the greatest effect on coagulation, clarification and settling.

Evidence to show that in coagulation by chlorinated copperas and acid the iron salt is effective in removing some of the material in true solution is presented by Lumb, *et al.* (190).

Biological Filters

A series of articles (15) (110) (111) (220) reviews present day practice in the design of high and low rate filters.

Dreier (87) calls attention to the need of standardizing the terminology to evaluate the performance and loadings of trickling filters. The present standard filter design loadings are considered too conservative. A loading of 500 to 800 lb. B.O.D. per acre-ft. per day is considered feasible on filters not less than 4 ft. deep.

Escritt (95) reviewed the design factors on the basis of experience in Great Britain.

The effect of artificial ventilation on the treatment of sewage by biological filters was discussed by Vosloo (280). It was concluded that artificial ventilation has no effect on the performance of biological filters.

The unstable character of biofilter sludge and the need for frequent removal from final settling units were experienced by Brown at Columbia, S. C. (57).

Kennedy and Roberts (167) reported on recirculation tests to determine the relative value of filter effluent versus final effluent. The results were not convincing. Their data again serve to illustrate that plants operating in a highly satisfactory manner are poor places to prove or disprove the merit of different operating procedures.

Additional operational data from the two-stage biofilter plant at Liberty, N. Y., are available (17). The comparisons are made between results obtained during the winter, when the plant is operated as a straight trickling filter, and during the summer when much heavier loadings require operation as a biofilter.

From New Zealand comes a report of the operation of biofiltration plants serving army camps (228). The average yearly B.O.D. reductions varied from 60 to 80 per cent. During the winter the reductions were 30 to 45

per cent. Flies and odors were not troublesome.

A general discussion of the uses of DDT against insect pests encountered in sewage treatment plants was presented by Hansens (123) and West (284).

Attempts at controlling flies with DDT, and the death of rabbits feeding on the surrounding grass are recounted by Rhame (225). Better removal of fly larvae was obtained by shortening the draining period from the flooded bed, giving a greater velocity. Further improvement was also obtained by changing the position of the distributor spray plates so as to get the heaviest possible surface washing action. This change reduced the frequency of flooding.

The results of a comprehensive experimental study of the control of filter flies by insecticides were presented by Tomlinson and Jenkins (269). They found that DDT and gammexane in dosages sufficient to kill *Anisopus fenestralis* and *Psychoda alternata* had no effect on *Lumbricullus lineatus* and *Achorutes subviaticus*. Large scale experiments showed that 194 lb. of creosote, 3 lb. of bleaching powder, or 75 lb. of DDT per acre controlled the emergence of *Anisopus*. One pound of gammexane or about 50 lb. of DDT per acre, when applied to sewage over a period of 1 to 2 hours, controlled the emergence of *Anisopus*.

Spraying parts of the surface of the filter with 10 lb. of DDT and 1 lb. of gammexane per acre controlled the emergence of *Psychoda* for 2 to 4 weeks. Five pounds of DDT or 1 lb. of gammexane applied to the sewage feed per acre controlled the emergence of *Psychoda* for 4 weeks. DDT and gammexane had no effect on the B.O.D. of the effluent or on nitrification, but the effluents were toxic to fish.

Treatment of sewage and textile plant waste on high-rate filters with a 75 per cent yearly average B.O.D. reduction is reported from Sweden by Johansson, *et al.* (159), in open filters at − 30° C. Forced ventilation or recirculation did not improve the B.O.D. reduction.

Activated Sludge

Mechanics of the Process

The utilization of organic substrates by activated sludge has been studied by Placak and Ruchhoft (214), who have presented data pertaining to the removal from solution, the oxidation and the conversion to protoplasm of 36 pure organic compounds. The substances studied include carbohydrates, alcohols, aldehydes and amino and other organic acids. Ease of removal of B.O.D. from solution seems to be more a function of the individual compound than of the class to which it belongs. The removal is accomplished by adsorption, oxidation, assimilation and synthesis, all occurring concurrently but varying in proportion with the time interval and the substrate material. As a general rule, 90 to 99 per cent of the compound is removed from solution by aeration with activated sludge for 24 hours. The proportions of the substances oxidized and converted to sludge are as follows:

Class	Per Cent Oxidized		Per Cent Converted to Protoplasm (Organized Sludge)
	Range	Mean	
Carbohydrates	5–25	13	65–85
Alcohols	24–38	30	52–66
Amino acids	22–58	42	32–68
Organic acids	30–80	50	10–60

Usually organic acids produce the smallest amount of activated sludge, and carbohydrates the largest. Normal activated sludge, when fed increased amounts of carbohydrates, quickly becomes acclimated and because of rapid adsorption and assimilation, will produce enormous quantities of sludge with high volatile solids content.

Pillai, Gurbaxani and Subrahmanyan (213) have reported that when cultures of the yeast *S. cerevisiae* were aerated with sterilized sewage inoculated with the protozoa *Epistylis*, purification of the sewage was poor. The injurious effect was traced to the products of yeast fermentation, such as acids and alcohols, rather than to the yeast cells themselves. The addition of lime to the mixture neutralized the acidity and improved purification.

According to Vladychenskii (279), activated sludge particles are negatively charged with an isoelectric point between pH 3.1 and 3.9. The viscosity of a sludge suspension reaches a minimum at pH 4 to 5. In high concentrations, sludge holds a considerable amount of water mainly by stereometric solvation, *i.e.*, in the structure which the sludge assumes at high concentrations. For example, with 1.25 per cent solids, the water bound by the sludge was 82.5 per cent, but at 0.628 per cent solids, the percentage of bound water dropped to 17.15. The maximum effective area of activated sludge calculated from absorption data was 100 sq. meters per gram.

Experimental work by Finch and Wright (101) has indicated that economic flocculation of sewage colloids may be obtained by mixing excess activated sludge with settled sewage. If one-third to one-sixth of the sewage flow is treated by the activated sludge process, the remainder of the settled sewage may be mixed with the excess activated sludge to remove the colloidal material. About 3 to 8 per cent of sludge by volume will remove one-third of the colloidal solids in 30 minutes.

Operation

After a study of the thickening of activated sludge, Bloodgood (49) believes that the maximum sludge concentration (expressed in percentage) that can be expected in an activated sludge plant is numerically equal to the sludge density index. When good activated sludge is settled in a cylinder, the volume of sludge does not decrease appreciably after 30 minutes. Further concentration depends upon a physical change in the character of the sludge. The concentration and the sludge index are affected by the B.O.D. loading and by the amount of aeration or oxidation of the sludge. Bloodgood regards as impractical attempts to concentrate waste activated sludge which has a poor initial index, unless the sludge is held long enough for partial decomposition to take place.

Bloodgood and Frazier (51) have reported the results of a combination of activated sludge and plain aeration at Indianapolis. An increase in sewage volume and concentration made it impossible to treat all of the clarified sewage by the activated sludge process. Some had to be treated by plain aeration in order to remove as much B.O.D. as possible and to maintain the river into which the plant effluent discharges in a satisfactory condition. On the average, about one-third of the sewage was treated by the activated sludge process and the remainder by plain aeration. The plant effluent averaged 45 p.p.m. suspended solids and 81 p.p.m. B.O.D.—removals of 88 and 68 per cent respectively.

The operation of the San Antonio plant has been described by Berg (46) (47) who has found that the most satisfactory results are obtained when the suspended solids in the return sludge are not less than 8 but not necessarily greater than 15 times the weight of the incoming suspended solids.

Rath (221) has described the operation of the Tallmans Island plant of New York City, where step aeration is provided. The flexibility supplied by step aeration has been used mainly to lessen the shock of sudden loads from industrial wastes or during storms.

It was necessary to store activated sludge during the shutdown for coal conservation at the Northern Outfall

Works of the London (Eng.) County Council (278). The paddles in one aeration set were operated at the highest possible speed to provide aeration and circulation of the mixed liquor. Once each day, the paddles were stopped and the sludge allowed to settle. Usually about 75,000 gal. (Imp.) of supernatant liquor of the total of 1,200,000 gal. were pumped out and replaced by raw sewage. No diffused air was used. When the plant was restarted the stored activated sludge enabled the plant to go into effective operation quickly.

From the results obtained at Indianapolis, Ind., and at Findlay and Marion, Ohio, Tolman (268) concluded that garbage solids are oxidized by the activated sludge process as readily as are sewage solids. Edwards (89), on the basis of review of diffused air type aeration plants, came to the conclusion that no arbitrary rules for the operation of activated sludge plants can be set because of the variations in the characteristics of the sewage and of the flow. Experience with each plant will set the best method of operation. The discussion is around the following controllable variables: (1) volume of air, (2) concentration of suspended solids in the aeration tank, (3) aeration period, (4) rate of sludge return, and (5) condition of sludge. These variables should be changed according to local conditions, seasons and fluctuations in load.

Design

Philadelphia's Northeast Treatment Works (244) is being converted into a 125 m.g.d. modified activated sludge plant. The air supply system providing 0.4 cu. ft. per gal. of sewage is equipped with electrostatic dust precipitators to minimize diffuser clogging. It is expected that the B.O.D. will be reduced from 200 to 50 p.p.m., which will leave sufficient oxygen in the Delaware River to support fish life.

Friel (103) gave a comprehensive cost analysis of the activated sludge plant at Abington Township, Pa. The plant is designed to handle 2.42 m.g.d. from a population of 20,000. It will provide for 1 hour primary settling, 6 hours aeration and 2.5 hours of secondary settling. Sludge digestion and sludge drying beds were also included. The total cost in December, 1946, was $638,800 as compared with $542,686, estimated on the basis of 1942 construction costs.

The proposed 4 m.g.d. activated sludge plant at Oshawa, Canada, will include the following, according to Williams (290): (*a*) combination preaeration and grit removal, (*b*) air diffusion by swing diffusers, (*c*) Tow-Bro sludge collectors. The diffuser tubes are to be so spaced as to provide tapered aeration.

Chlorination

The applications of chlorine in sewage treatment practice continue to increase in number and variety. In addition, new chlorination processes have been developed to treat specific industrial wastes. Reports on basic research relating to sewage and industrial waste applications of chlorine, however, have been very limited.

Published (68) during 1947, the "Chlorine Manual" provides useful information concerning the characteristics of chlorine and recommends safe handling procedures. A subcommittee of the Sewage Works Practice Committee of the Federation has been assigned the development of a Manual of Practice on "The Use of Chlorine in Sewage Treatment." A need exists for such a manual, and it is reported to be in a late stage of preparation.

Chlorination Research

Research studies of the virucidal action of chlorine, while made using contaminated water as the medium, are of theoretical interest in the treatment of sewage. Lensen, Rhian, and Stebbins (187) report the Lansing strain

of poliomyelitis virus to be inactivated in water by chlorination at pH values ranging from 6.85 to 7.4 when residuals consisting of chloramine and some free chlorine were present after a contact period of 10 minutes. In general, the results of experiments indicate that residual chloramine values of 0.5 to 0.75 p.p.m. usually inactivate the virus in less than 2 hours contact, while residual chloramine values of 0.2 p.p.m. or less fail to inactivate the virus. Working with human subjects, Neefe, Baty, Reinhold, and Stokes (206) found the dosages of chlorine that are adequate for inactivation of the bacterial pathogens occurring in drinking water may not be adequate for the inactivation of the virus of infectious hepatitis, particularly if the water has a high content of unoxidized organic material.

In recent studies of the virucidal action of chlorine, it has been found important to distinguish between chlorine residuals existing as free or as combined available chlorine. Definitions of the two types of residuals have been published (97) and suitable test methods are available to make the distinction. In normal sewage chlorination practice, however, only combined available chlorine residuals exist.

Chlorination of sewage effluents was attempted by McLachlan and Gaillard (196) with the objective of the inactivation of poliomyelitis virus. For this purpose complete bacterial sterility was sought. The varables studied were (1) chlorine dosage which varied from 0.2 to 120 p.p.m., (2) contact time which varied from 10 minutes to 24 hours and (3) chlorine demand. Coliform organisms were tested in 10 ml. portions and plate counts in 1 ml. portions. The studies were made with sand filter effluent. With 10 minutes contact time chlorine doses of 15 to 95 p.p.m. were required to destroy all the coliform organisms and colony-producing organisms in the above stated portions of the effluent. It required a great deal more chlorine to destroy all growths on agar in 1 ml. portions than to get a negative *B. coli* test in 10 ml. portions. It was concluded that sterility as indicated by negative presumptive in 10 ml. portions and a negligible plate count with 1 ml. sample may be taken as an index of the efficiency of chlorination for the inactivation of the poliomyelitis virus. The choice for this purpose is between high doses (100 p.p.m.) with short contact periods and lower dosages with longer contact periods (24 hours). The disadvantage of the first is the adverse effect of high residuals in the effluent on the soil or stream, depending on the final method of disposal. The second alternative entails the cost of large contact tanks.

The chlorine demand concept as applied to disinfection of sewage effluents is criticized. No indication of breakpoint has been observed with dosages up to 120 p.p.m.

In discussing the toxic effect of industrial wastes, Hedgepeth (137) points out, "Sanitary engineers do not normally think of chlorine as a pollutional substance, but it must be classified as such if "too much" is discharged into game fish streams." His statement is of interest in connection with a report (31) summarizing unpublished investigations by the British Water Pollution Research Board. This report cites experiments demonstrating free chlorine in a concentration as low as 0.3 p.p.m. to be appreciably toxic to fish. Even when chlorination is regulated in such a way that no residual free chlorine is present in the effluent discharged to the stream, it may still be fatal to fish life. Chlorination of effluents containing thiocyanates (from gas works liquor or other chemical wastes) is found to produce especially toxic reaction products. The limited data cited do not indicate whether toxicity was related to the chlorinated effluent, or to the chlorinated effluent after dilution. For practical consideration, these studies

must be related to the dilution and the chlorine demand created by the receiving stream.

Biological treatment of wastes containing certain chemical substances may be difficult if the wastes are chlorinated. Harlow (124) states that some chlorinated phenolic wastes require special treatment, and that chlorine substitution in the para position seems to render these compounds difficult to treat biologically.

The chlorine demand of activated sludge effluent has been found by Berg (47) to vary inversely with the degree of purification. He finds a good effluent (low in ammonia and high in nitrites) to have a higher chlorine demand than does a less highly purified effluent (high in ammonia and low in nitrites). The amount of chlorine required by the former is 30 to 35 lb. per mg., while the amount required by the latter is about 15 pounds. It is considered difficult to estimate the bacterial quality of an oxidized effluent by the chlorine residual present.

Chlorine Applications

Cameron (64) has provided data on the unusual chlorinating facilities in use at Atlantic City, N. J. A ton container storage platform and scale house are located on the mainland, and each of 2 scales holds a 1-ton container of chlorine. Liquid chlorine is sent through 1,600 ft. of pipe (provided with 5 expansion bends), supported on a footbridge, to the chlorine building on an island where the sewage treatment plant is located. This building houses liquid chlorine evaporators and solution chlorinators. Liquid chlorine enters the pipe line through a ball check valve, designed to stop the flow of chlorine in the event of a break in the chlorine line. The installation has given satisfactory service for a period of 5 years.

An unusual situation exists at the Niagara Falls, N. Y., plant which treats sewage containing industrial wastes by fine screening and chlorination, treatment being largely to reduce bacterial pollution of the Niagara River. Smith (254) reports that the high chlorine content of certain wastes necessitates only part time operation of chlorinators at the plant. Residual tests are made at least hourly on both influent and effluent. Average residual chlorine in the plant effluent is 3.4 p.p.m., the minimum being 0.2 p.p.m. and the maximum 280 p.p.m.

According to Casey (66), consumption of chlorine at the Richmond-Sunset plant of San Francisco is 30 lb. per m.g. for prechlorination to control odors, and 90 lb. per m.g. for post-chlorination. Kennedy (166) describes the program under way to eliminate discharge of untreated sewage at San Francisco; additional chlorinating capacity will be provided at this plant, and similar facilities will be included in the new North Point plant.

Chlorination for Disinfection

An effluent of consistently good bacterial quality has been produced (166) at the Richmond-Sunset plant. This is demonstrated by analyses of the beach waters, which show a coliform index of less than 10 per ml. (the limit set by the State Department of Public Health).

Chlorination of the entire flow of Los Angeles sewage, averaging 198 m.g.d. during 1947, permitted (11) lifting of a quarantine from 4.5 of the 11.5 miles of beaches previously closed to public use because of pollution. This treatment required the application of 18 tons of chlorine per day. Until adequate treatment and outfall facilities are provided, the sewage receives only coarse screening and chlorination during the 5-month bathing season. The criterion adopted for safe bathing is that less than 20 per cent of the samples taken over a period of time shall have 10 or more *E. coli* per ml. Beach quarantines were placed and removed on this basis. This installation

has a maximum capacity of 21 tons per day and is second in size only to the world's largest (at Detroit, 27 tons per day capacity); it will become a part of the new activated sludge treatment plant. The demand of this sewage is such that chlorinating capacity is inadequate during certain periods of the day. Of total daily operating costs of $1,494, the cost of chlorine is $1,165. In early September, 1947, due to a shortage of chlorine in California (12), the application of chlorine at Los Angeles was stopped. This necessitated reimposition of the recently lifted quarantine on nearby beaches. The shortage of chlorine was caused by lack of electric power at a West Coast electrolytic chlorine plant; the power shortage was not expected to be of long duration.

Johnson (160), summarizing operating data from the Buffalo plant, shows primary settling and chlorination to reduce presumptive coliform bacteria from 90,900 per ml. of raw sewage to 1,830 per ml. of treated effluent. Chlorine demand of the raw sewage averages 4.6 p.p.m. However, supernatant liquor from sludge digesters has an average chlorine demand of 331 p.p.m., and the addition of this liquor raises the total demand to an average of 4.91 p.p.m.

Chlorination in Secondary Treatment

Operating studies involving a large number of B.O.D. tests on activated sludge effluent before and after chlorination are reported by Berg (46) to show that chlorination at the San Antonio, Texas, plant accomplishes an average B.O.D. reduction of 30 per cent. The extent of B.O.D. reduction is found to depend on the amount of chlorine applied, and not on the residual obtained.

Rath (221) describes facilities for thickening activated sludge at the Tallmans Island, N. Y., plant. During cold weather, dilute activated sludge can be pumped from thickeners to primary settling tanks where it mixes with primary sludge and settles readily. In hot weather, chlorine is required to prevent the sludge from becoming septic; otherwise bulking would prevent maximum concentration of sludge needed to avoid overtaxing digesters. The data show that chlorine was applied in a 25 p.p.m. dose for this purpose during the summer.

Chlorination is found beneficial in the Marshalltown, Ia., activated sludge plant (19) where it is employed to manufacture ferrous or ferric chloride for seasonal pretreatment of cannery wastes. New plants described by Friel (103) and by Williams (290) include chlorination as a part of activated sludge treatment, for application to return sludge and for effluent disinfection.

Chlorination in Industrial Waste Treatment

A comprehensive discussion of the characteristics of wool scouring wastes, of older methods of treatment, and of a new treatment process employing calcium hypochlorite solution is provided by Faber (96). About 98 per cent of the grease contained in the raw waste is reported to be removed, and about 75 per cent of the grease is recovered and marketed. Practically all of the suspended solids, and from 80 to 90 per cent of the B.O.D., is removed by the treatment. In a discussion of this paper it is pointed out by Campanella that chemical engineering principles, rather than sanitary engineering methods, may be required in order to devise suitable methods for treating certain types of industrial wastes.

Dobson (82) has reviewed methods for treatment of metal plating wastes containing cyanides, and has described in detail the chlorine method which is reported to be simple, highly efficient, and competitive in cost with any other method. Reactions given show that chlorine first oxidizes cyanides to cyanates and then, in a second reaction

slower than the first, oxidizes cyanates to carbon dioxide and nitrogen. Excess chlorine is required in the second reaction. At least 7.35 parts of chlorine are required per part of cyanide, and the pH value of the treated solution must be maintained at 8.5 or above. Either caustic soda or lime may be employed as the alkali. Results show that when free available residual chlorine is present after the reaction no cyanide will be present.

At an industrial plant in Meadeville, Pa., Barnes (40) describes the treatment of cyanide wastes by means of excess iron and lime to form harmless salts of cyanogen. An increase in the volume and concentration of cyanides led to study of the chlorine method of treatment and to its adoption on full plant scale. Average cyanide content of these wastes is given as 212 p.p.m. before treatment, and as 1.2 p.p.m. after treatment. Oeming (208) also discusses the chlorine process of treating cyanide wastes and considers it the method having the widest range of adaptability.

For temporary treatment of tannery effluent, Howard (151) reports that the addition of 300 p.p.m. of chlorine effectively coagulated suspended solids and materially corrected odor conditions in the receiving stream. According to Marshall (191), beet cannery wastes received at a primary sewage treatment plant increase the chlorine demand (the waste has a chlorine demand varying from 220 to 460 p.p.m.). Also, the red color of the wastes persisting through the plant makes it impossible to use the regular orthotolidine test for residual chlorine. The results cited indicate that the chlorine dose has not been adequately increased; when only domestic sewage is treated, the effluent has less than 100 *E. coli* per 100 ml.; but when beet canning wastes are received, the effluent may contain as high as 1.25 million per 100 ml. Labratovich (181) describes the effect of lime wastes from an acetylene manufacturing plant upon chlorination of sewage. The average pH value of 7.3 to 7.7 was increased to a value of 8.4 to 8.9 and, despite the maintenance of 0.2 p.p.m. residual chlorine after 20 minutes contact time, disinfection efficiency was materially decreased. During the periods these wastes were received, an increase of 19,000 bacteria per ml. over the annual average of 3,400 was noted.

Chlorine Products in Sewage Treatment

The development of Cloroben treatment in Los Angeles has been reviewed by Brown (58), who reports more than 50 dosing stations to be in operation; in these, the application rate is varied with the sewage flow and with the Cloroben demand of the sewage. Inhibition of hydrogen sulfide and reduction of relative humidity within the sewers (both are factors involved in formation of sulfuric acid and in the deterioration of concrete) are largely accomplished by applying a Cloroben dose varying from 1.0 to 2.0 p.p.m. A paper by Appel (38), also with reference to Los Angeles practice, points out that the sulfide content of sewage reaching the Hyperion plant was formerly from 5 to 10 p.p.m. but has been reduced by Cloroben treatment to not over 1.5 p.p.m. Operation of 4 ventilating stations, installed to reduce hydrogen sulfide in the outfall sewer atmosphere, is no longer required; the resultant saving accomplished is $20,000 per year.

Chlorine continues to be used in certain sewage treatment plants for production of ferrous and ferric chloride by means of the Scott-Darcey process. At San Diego, Calif., Quartly (218) describes application of chlorine and ferrous chloride to raw sewage for odor control and for control of hydrogen sulfide. At Wickenburg, Ariz. (22), ferrous chloride is applied to raw sewage for odor control, and ferric chloride is applied for coagulation.

Chlorinated copperas is employed in

routine operation of the Guggenheim process sewage treatment plant at New Britain, Conn., according to data published by Szymanski (263).

Sludge Digestion

Operation

The practical and theoretical aspects of sludge digestion are concisely discussed by Schlenz, Buswell and Tatlock (240) (60) (265). Due to the role digestion plays in stabilizing and reducing the bulk of sewage sludge Schlenz (240) observes that a properly designed and operated digestion system should serve to moderate and adjust the effects of peak loads in operating clarifiers. He discusses the objects, aims and control of digestion and shows facilities for maintaining the desired results. The control of proper balance in volatile acids is considered superior to using pH control.

Buswell (60) deals with the microbiology and theory of anaerobic digestion. He considers the problem primarily from a purely chemical standpoint and regards "sewage purification as simply the removal of carbon-hydrogen compounds." He also states that "anaerobic fermentation has long been recognized as the cheapest method of removing organic matter, carbon and hydrogen from sewage or waste liquors where conditions are suitable for its application." Due to the cheapness of this process it properly deserves the intensive study it is beginning to receive. He describes the characteristics of the few organisms responsible for methane production in anaerobic fermentation. As a result of bacteriological research Buswell feels that we are now nearing the goal where we can control the digestion process in a manner approaching that of other fermentation industries. He lists four conditions upon which high digester yields depend: (1) large surface, (2) volatile acids control, (3) control of scum formation, and (4) elimination of fibrous materials.

In discussing the foregoing, Tatlock (265) aptly states that intelligent procedures in digester operation are frequently better than increasing digestion space in a given plant. He stresses the importance of balancing the addition of fresh sludge with digested withdrawals in digestion tanks, proper regulation of temperature throughout the entire tank, and agrees with Buswell and Schlenz on the control of volatile acids and scum.

Rath (221) reports on sludge digestion and gas engine operation at the Tallmans Island plant of New York City. On the other side of the Atlantic Townend and Lockett (270) contribute some more information on sludge digestion at the Mogden Works of West Middlesex, England. The sludge from the primary digesters is pumped 7 miles to the disposal site where prolonged settlement in secondary storage produces clear supernatant and digested sludge. Yeast waste caused trouble in the sedimentation tanks, which problem was overcome by delaying the fermentation of the waste for an hour by dosing the waste at the factory outlet with copper sulfate.

Heating

The various methods of heating sludge during digestion are evaluated and discussed by Miles, Rudolfs, Rawn, Bacon and Ludwig (200) (231) (222). Miles (200) lists the factors peculiar to sludge digestion, basic principles of heat exchange and the various kinds of heaters. His criticism of the misuse of the term "radiant heat" for using the tank walls as a heat exchanger in a digester full of highly aqueous sludge is well taken. In the case of submerged gas burners his raising the question of the danger of introducing an open flame into a digester may, at first sight, seem also well taken. However, the open-type burner can be used outside of the digestion chamber in a manner quite similar to the use of steam at San Diego (217),

without any danger, without the necessity of diluting digestion gases with combustion gases, and with all of the advantages deriving from quick accessibility. Keefer (163) apparently overlooked this easy application.

Miles favors external heat exchangers over internal heating coils on the grounds of accessibility, flexibility and ease of heat control. Rawn, Bacon and Ludwig (222) agree with this viewpoint and stress the thermodynamic advantages gained from direct heat exchange. Rudolfs (231) emphasizes the factor of heat losses in designing digesters and agrees that the sludge heating methods most commonly used need improvement.

External heaters employing live steam, as advocated by Rawn, Bacon and Ludwig, certainly demonstrate improvement in the two following references.

Gunson (119) reports gratifying results at Denver in heating primary digesters by means of direct injection of live steam into the sludge. The use of a steam injector eliminates the use of a special recirculating pump, while supplying all the heat necessary for digestion. After 8 years of service with heating coils the injectors were installed between the raw and digested sludge lines on the primary digesters. Their use not only eliminated colder, dormant pockets in the digester but completely removed the scum blanket that had accumulated. The temperature of the tank contents was also raised from about 85° F. to a more uniform and beneficial range of 95° to 105°.

Rawn *et al.* in their foregoing discussion refer to the use of live steam at San Diego. This installation is described by Quartly (217). He relates the successful recourse to this method of heating to bring definitely overcrowded digesters back to maximum heating efficiency in San Diego. The original hot water heating facilities were inadequate to maintain digestion temperatures above 83°. Now a constant-level sludge heating box of concrete is used on the roof of the digester control building to permit maintaining a constant level of raw sludge during its heating by live steam and to insure gravity flow of heated sludge to the primary digesters. This 6-ft. cube concrete box has a removable cover and contains a partition having a constant-level overflow weir. Unheated raw sludge and live steam enter the constant-level chamber.

Notwithstanding the extreme simplicity of these two methods of heating digesters and the logical criticism offered by Miles about imbedding heating coils in the cement walls of a digester, this latter method of producing heat transfer is to be used in the digesters designed for Puyallup, Wash., according to Sphar (257). It will be interesting to learn how the design for Puyallup solves the problems of expansion and contraction of the imbedded tubes carrying water at temperatures above 140° F., and of the lowered resistivity of the hot inner concrete tank surface to solution action by HCO_3^- and other solute ions at 140°. Furthermore, there is the subject of heat loss, to which Rudolfs directs attention. With solid digester walls heated to 140° they will have to be guarded well against reverse heat losses by a most efficient outside insulating barrier.

This subject of heat losses is mathematically treated by Montgomery (203) and Candee (65). These authors present two methods of computing heat losses in digesters. The former utilizes graphs and the latter a relatively simple tabulation.

Scum

Gilbert (109) shows the need for preventing scum formation in sludge digestion tanks and emphasizes the role played by scum breakers in maintaining volumetric efficiency in rectangular and circular digesters.

Doman (86) presents a logical procedure for approximately determining the location and thickness of layers of scum, supernatant and sludge in digesters by rapid volumetric determinations of settled solids in collected samples. The accuracy depends on vertical spacing of sampling pipes in the lower and upper halves of a digestion tank and on daily recordings of samples taken from these pipes plus an extra sample from one of the decanting pipes.

What can happen to a fixed-roof digester when a heavy scum accumulation seals the tank outlets is described by Albertson (2). The primary digester at Highland Falls, N. Y., became a closed hydraulic cylinder with its outlets sealed and with sludge delivered to the tank by a plunger pump. The result was a ruptured digester roof.

Rankin (219) goes into the problems of persistent scum accumulation in digesters, their various causes and remedies. He classifies scum-forming materials and presents examples of small plants where the elimination of scum-forming materials of industrial origin at their source has solved scum problems. He also discusses control measures at the digester by recirculation of liquid digester contents and digester design for scum control. Schlenz (240) discusses the problems presented by Rankin and shows proprietary methods of operation and design for scum control. In another article (241) Schlenz reviews methods for controlling digester scum by recirculation of warm digester liquor into the scum zone.

Flood (102) also argues that scum particles must be well moistened by recirculation of warm liquor from beneath the scum to the zone above it. Scum must also be maintained at optimum alkalinity and temperature and kept saturated with biologically active organisms. He shows a method of doing this in fixed-cover digesters. The construction also permits the use of external heat exchangers.

Gas Utilization

Gould (115) presents an informative review of gas utilization experience gathered in the various sewage works of New York City. However, one should remember that these particular plants are our greatest source of experience because they utilize more digester gas in combustion engine power units than in the balance of the United States and Canada combined. There is nothing unique in digestion practice in these plants and the experience gained with gas engines has been highly satisfactory. The author outlines conditions favoring digestion in the New York City plants and gives an account of the various operating installations with outlines of those that are projected. He also cites the tests made at Tallmans Island with the Dual-Fuel engine that has attracted so much attention. This engine was converted to the Diesel cycle to provide higher efficiency. Its advantages in economy are promising enough to warrant further installations.

Boehm (52) discusses the Dual-Fuel engine further, emphasizing its higher thermal efficiency due to high compression, and presents further statistics gained at Tallmans Island. He also points out that where there is an abundance of gas and a number of engines in a plant, only as many of the Dual-Fuel type will be required as are necessary for initial plant functioning and continuity of operation.

Larson (184) shows how 1 of 2 small gas engines has been effectively used at the Battle Creek, Mich., plant to pump over 22 billion gallons of sewage for 80,000 hours during the past decade. It used about 40 million cu.ft. of digester gas.

A somewhat similar story comes from Martin (192) of Green Bay, Wis., where two gas engines produced a good net profit in 8 years of operation. The

use of detergent oil has reduced oil consumption. At Fort Wayne, Ind. (27), similar savings are also emphasized. Here the 465 h.p. Worthington gas engine has made a saving of $199,000 in 6 years of operation. The original cost was $30,000.

Such benefits cannot be obtained without proper maintenance and operation. Kraus (178) handles this subject well in relating the experiences gained at Peoria, Ill., in carrying out the program for maintenance at that plant. The thorough information covers a period of over 10 years of careful operation in a plant having no standby equipment other than purchased power. Two gas engine units are involved, *i.e.*, one of 300 h.p. driving a 200 kw. generator and another of 535 h.p. driving a Roots-Connersville blower supplying 12,600 cu.ft. of air per minute. The author supplies valuable data on liner and piston ring wear, lubrication, bearings, valves, ignition, water circulation and power cost. The engines generated about 97 per cent of power requirements in 10 years and have saved the Peoria Sanitary District $36,000 annually. The estimated cost of power produced is 2.6 mills per kw. hr.

A digest of a recent round table discussion on servicing gas engines is also presented in *Sewage Works Engineering* (24).

Garbage Digestion

Backmeyer (39) describes experience gained with dual disposal at Marion, Ind., during the past 5 years. He also reviews a series of experiments involving garbage digestion in small units. Originally in this plant garbage was ground and added to the raw sewage at the wet well. This required excessive time for drawing primary sludge to digestion, increased the secondary treatment load, and resulted in too much unsightly material getting by the grease skimmers. A separate garbage receiving and mixing well with piping to digestion was installed and proved successful. Lime is used to adjust the pH if ground garbage is left too long in the well.

The author also reports interesting studies made to determine what percentage of the total gas generation comes from sewage solids and from garbage solids. During the summer months the amount of garbage ground increases 400 per cent and gas production increases 30 per cent. Good circulation of primary digested sludge is essential to uniform digestion temperature and maximum reduction of the volatile matter. Digestion of ground garbage with sewage solids increases the suspended solids in the supernatant. In adding ground garbage directly to digesters, in order to avoid trouble, it is necessary to remove grit and various other items of indestructible material.

Tolman (268), from a study of a survey of plants receiving garbage, came to the conclusion that: (*a*) garbage solids are digested readily, (*b*) gas production is increased in direct proportion to the amount of garbage volatile solids added, and (*c*) the digested sludge is of somewhat lower solids content. A digester capacity of about 3 cu. ft. per capita was necessary for garbage added at the rate of 2 tons per m.g. of sewage. Most of the plants had overloaded digesters.

Solids Content

Keefer (164) reports on laboratory digestion investigations of Baltimore sludge cake of high volatile and solids content. These experiments involved the use of sludge cake containing about 30 per cent solids resulting from coagulating with ferric chloride and filtering mixtures of raw and seeding material. Although the conclusions are that sewage sludges digest over a considerable range of contents in solids, it should be interesting to investigate this problem without the use of bactericides like ferric chloride, *e.g.*, on

sludges that have been concentrated by centrifuging.

Phosphates

Rudolfs and Stahl (233) discuss the effects of phosphates on sludge digestion. The percentage of phosphates expressed as P_2O_5 is higher in digested than in primary sludge. This indicates that the phosphates are largely precipitated. The indication is strengthened by the fact that the P_2O_5 content increases in sludge resulting from chemical treatment. According to standard works on physiological chemistry, the insoluble phosphates found in feces are largely of insoluble "earthy" phosphate origin.

Experiments involving additions of various soluble phosphates to seeded raw sludge samples were undertaken. The authors state that in general, all phosphorous compounds added had the effect of retarding digestion and produced less combustible gas. No direct correlations were found between the quantity of phosphorus present and the rate of decomposition.

Rudolfs and Falk (234) subsequently report efforts made to determine the effects of phosphorous compounds on the clarification of digester supernatant. There were no pronounced effects and the use of phosphoric acid produced the least of any.

Toxic Effects

Wischmeyer and Chapman (292) report on experiments conducted to determine the toxic effect of various concentrations of nickel salts on sludge digestion. The results indicate that nickel sulfate and nickel ammonium sulfate containing up to and including 500 p.p.m. nickel do not retard normal digestion, but rather tend to increase activity. Higher concentrations definitely retard activity.

Rudgal (230) reviews the effects of copper wastes on digestion as reported in the 1946 Annual Report of the Kenosha, Wis., plant. These effects have been detrimental and costly. The condition is being corrected through bypassing the toxic waste into Lake Michigan without treatment. In the foregoing reference (270) to the Townend and Lockett report on digestion at Mogden, it will be recalled that copper sulfate was used to dose yeast waste before dumping it into the sewer. Evidently this is a case of using a toxic electrolyte in small enough quantities to eliminate trouble in plain sedimentation without causing trouble in digestion.

The effects of beet canning waste on digester gas production at Geneva, N. Y., are shown by Marshall (191). During the canning season there is about a 29 per cent increase in gas production but the methane content is lower and more gas is required to maintain the desired digestion temperature. This may be a case of the effect of volatile acids mentioned by Schlenz and Buswell (240) (60).

Design

For several years the digester supernatant at the Richmond-Sunset treatment plant in San Francisco has been partially clarified by elutriation. This procedure also concentrates the solids. In the design of the enlarged Richmond-Sunset plant, Kennedy (166) indicates how elutriation will be used first to concentrate the solids and clarify the supernatant between stages of digestion, and then used in the usual manner after digestion, to further reduce coagulant requirements.

Vermette (277) outlines methods of reducing construction costs of sludge digesters in small plants.

Sludge Disposal

Sludge Drying Beds

Aids for designers in determining the cost of artificially heating and ventilating glass-covered sludge drying beds are presented in an article by Kozma (177). Such heating and ven-

tilating are stated to afford the following advantages over unheated covered beds: (*a*) drying throughout the winter is feasible, (*b*) areas of drying beds can be further reduced, (*c*) capacities of digestion tanks may be reduced.

The tables and diagrams presented are set up with a high factor of safety because of the few operating data available. Whereas some feel that the covered bed is too costly for its advantages (and disadvantages) (63), a reappraisal in the light of heated beds may well be in order. From the hypothetical cases worked out by the author it appears, based on the liberal allowances made, but with high initial sludge concentration, that the installation of heating equipment in beds may be justified only where high land values, expensive construction, or lack of space for further plant expansion would force designers to resort to more costly sludge drying methods. The author feels that this is particularly true in small plants where vacuum filtration would be impractical, unless perhaps the new cord filter could win its position in such cases.

Kunsch (179) gives comparative data on sludge cake removal from drying beds by means of an existing industrial railway, an overhead scoop loader, bucket elevator, side-bin tractor and dump truck. Advantages and disadvantages of each are quoted. Lack of labor to operate the industrial railway system originally provided led to a review of other methods. For Urbana-Champaign conditions direct loading to trucks was adopted.

Sludge Conditioning and Dewatering

Changes in the viscosity of humus sludge during coagulation were studied by Inkster (154). The coagulants used were ferric chloride, acidified ferric chloride and alumino ferric. In general the sludge passed through a maximum viscosity at some coagulant dosage. In the case of ferric chloride there was some correlation between optimum dosage for coagulation and dosage at maximum viscosity. The phenomenon could be explained by electrostatic attractions between sludge particles arising through uneven distribution of charge, when adsorption of coagulant ions took place. The presence of acid depressed the viscosity maximum and it was suggested that this was due to the displacement of coagulant ions by acid ions. There is a probable linear relationship between dosage of sludge with ferric chloride for effective drainage and dosage at maximum viscosity, but the following factors interfere with this relation: (1) the very high variance of the results of initial viscosity measurements which arise through lack of uniformity in mixing, (2) the marked influence of acid, which leads to a sharply defined viscosity at low coagulant concentration, although the acid inhibits coagulation, and (3) the specific nature of the viscosity maximum for the type of coagulant used.

Laidlow (183), on the basis of experimental work, attempted to evaluate the effect of reducing agents in digested elutriated sludge on the quantities of ferric chloride necessary for vacuum filtration. This was arrived at by comparison of filtration rates of aluminum chloride and ferric chloride. For the same sludge, 10 to 15 per cent less aluminum chloride than ferric chloride was required. Comparisons were also made of the required dosages of these two chemicals, when the sludge was maintained in an oxidizing state by the addition of chlorine. With such treatment there was little difference in ferric and aluminum dosages.

Discussing the merits of sludge elutriation, Genter (107) points out that the use of lime and ferric chloride to condition ripe sludge for filtration may result in as much as 45 per cent more solids to be handled than if elutriation and simple ferric chloride conditioning are used. The effect of added B.O.D. from the sludge elutriate on primary

and secondary treatment is shown to be negligible.

The problem of decreased digester capacity as a result of "dirty supernatant," *e.g.*, liquor containing a considerable amount of sludge, is described. Elutriation may assist in relieving the problem by producing more compactible solids from the supernatant. These may be returned, dried on sand filters, or filtered.

Evans and Roberts (94) review the former experiences with heat treatment and pressing of sewage sludge (Porteus process) in Horsham and Halifax, England, and add to it the information available from the newer installation of this kind at Luton. At Halifax activated and humus sludges are treated, while the other plants treat both primary and secondary sludges. The Luton plant treats sludge from 100,000 population and has been in operation for a year. No chemicals are used for conditioning. The sludge is heated to 300 to 400° F. (370° F. recommended optimum) for 15 to 30 minutes. As a result of heating, the sludge becomes filtrable and loses a considerable portion of the organic matter to decant and press liquor (10 to 20 per cent). The liquor contains 58 to 79 per cent of the original nitrogen in the sludge. The liquor is returned to the plant influent and, as has been previously reported from Halifax, is amenable to a number of different separate treatment processes.

Heat exchangers are incorporated in the system and provide nearly 80 per cent of the total heat required to preheat the fresh batch of sludge. The sludge is heated in pressure vessels by steam jets at the bottom. After cooling, the heated sludge is allowed to settle for 3 hours to 12 per cent solids and then pressed at 100 lb. per sq. inch. At this stage the cake contains 40 to 50 per cent moisture, which has to be further reduced if the sludge is to be used as fertilizer or as a source of fuel in the system. Air drying is satisfactory except in the winter. When dried under a shed in heaps, heat generation takes place. Incineration of the press cake for steam generation is feasible, provided adequate methods of drying are available. Under these conditions the process is said to be independent of outside fuel.

When primary sludge is to be heat-treated, it is necessary to screen the sewage to prevent checking of the system. Heat treatment can readily be applied to digested sludge.

A 150 sq.ft. vacuum filter employing $\frac{5}{32}$-in. braided cords as a filtering medium has been in service this year at Plainfield, N. J. (175) (176). The cord is threaded around rollers in such a way that the cords are washed prior to being returned to the drum. The conventional drainage system inside the drum is dispensed with, since the lower set of cords provide a space along which water removed from the solids left on the top set of cords may travel to an external radial filtrate piping system which utilizes a combination filtrate and vacuum pump unit. No air blow is required at the discharge end. The filter, which is now available for demonstrations as a mobile unit, appears to possess a number of practical advantages. At Plainfield the filtrate is reported to be of good quality (20 to 30 p.p.m. of suspended solids). Additional filter runs should be made on other sludges in order to demonstrate beyond question that a satisfactory filtrate can be produced for return to the raw sewage.

In 1945 the Wyandotte, Mich., sewage treatment plant (188) installed facilities for using carbide lime, a by-product from the manufacture of acetylene gas, as a sludge conditioning chemical prior to vacuum filtration. Comparative costs from January 1, 1944, to June 30, 1945, when pebble lime was slaked, and from July 1, 1945, to December 31, 1946, when carbide lime slury was used, indicates a saving of about $5,000 annually with

carbide lime. Leonhard also reports less attention by operators to the lime handling equipment, no inert material requiring removal from the basement sump and considerable saving in cleanup labor because of lime dust elimination. Burley, discussing Leonhard's paper, reports that a decided economy has been effected through its use at Detroit following the Wyandotte experience. At both plants little or no change in the ferric chloride dose was required. At New Britain, Conn., carbide lime has been used for sludge conditioning since 1937 when the new plant started operations. In addition to savings in chemical costs, Szymanski points out that the lime slurry volume aids in control of the sludge incinerator temperatures.

Sludge Incineration

Schroepfer (245), in discussing sludge incineration problems, lists the incinerator installations in the United States from 1934 to 1946. At Minneapolis-St. Paul the economy of raw sludge incineration overhauling to disposal was forcibly brought out during World War II when, as it seemed likely that incinerator parts might not be procurable, bids were received from contrators to haul the sludge a distance of 1,000 to 2,000 ft. and cover it with earth. The lowest price was $0.60 per ton compared to the cost of incineration and ash disposal of $0.42 per ton. As might be expected, Schroepfer finds the costs of incineration to vary widely with the tons per day capacity, type of sludge and other local factors. Owen, discussing Schroepfer's paper, suggests that proper design of an incinerator requires determination of the carbon, hydrogen, oxygen, nitrogen and sulfur content of the sludge rather than its volatile content. The calorific value must also be determined. He suggests that preferably six months to a year should lapse between the start of vacuum filtration of sludge and the design and installation of an incinerator, to familiarize the operators with vacuum filtration problems and obtain what one might term a normal sludge cake for the plant in question.

Sludge as Fertilizer

The chemical analysis, results of greenhouse tests, and field experiments with 2 raw sludges, 1 digested sludge and 1 activated sludge are compared by Bear and Prince (42), with the results obtained with cow manure. In the pot experiments sudan grass was grown with and without commercial fertilizer additions. In field experiments corn was grown for a period of 4 years. During the first 3 years manure and sludge were applied every year in the fall. The moist sludges were applied at the rate of 20 tons per acre and the dried activated sludge was applied at the rate of 2 tons per acre. The yields of corn as silage were determined. The nitrogen and phosphorus contents of the added sludges and manures were not equal.

Field experiments with silage corn showed that the weakest point in the sludges was their low potash content. When a supplement of muriate of potash was added, the yields averaged as high as those produced with cow manure without extra potash.

The moist sludges had an objectionable odor. Lime applied to the sludge during storage keeps the odor, flies and rodents under control. Odors were controlled by mixing the sludge with soil and applying it before plowing. If sludge is used year after year on the same land, the soil should be tested to determine how much supplemental lime should be added, as some of the sludges tended to make the soil acid.

Stephenson and Bollen (258) reported that a lagooned digested sludge, sun-dried and shredded, had a composition and fertilizing value somewhat similar to that of a good farmyard manure. It had a nitrogen content 1.8 to 2.2 per cent. A considerable portion of the nitrogen in the sludge was

in nitrate form. The material was well-adapted to use where crops are to be planted soon after its application to the soil, and on crops where vigorous quick growth is desired. There appeared to be little danger of spreading any disease by using the sludge to grow vegetables. Garrick (104) reported that the fat content of raw sewage sludge on drying beds decreased from 30 per cent to 10 per cent in 1 month during the summer, and to less than 1 per cent in 9 months. An outdoor compost was made with straw, to which $CaCO_3$, ammonium sulfate, superphosphate and sludge were added. In 45 days most of the fatty substances had disappeared. Similar experiments, conducted under laboratory conditions with greatly reduced sampling errors, gave similar results. Saponification values showed that fatty acids are broken down quickly but the unsaponifiable materials disappear more slowly. The addition of ammonium sulfate enhances the decomposition of fatty substances in the straw compost.

Mechanical Equipment

The first appearance (10) of several new items of equipment was marked at the Federation's annual convention in San Francisco. These included the "Thermopilot Levelling Control," a General Electric product, which controls liquid surface elevations in tanks, acting automatically as a result of temperature changes in the sensitive parts of the control. There are no moving parts in the tank.

Wallace and Tiernan's new sewage chlorinator can automatically change the rate of chlorine delivery at any predetermined time to coincide with anticipated changes in rate of sewage flow.

An aerator, introduced by the Chicago Pump Co., consists of thin, stainless steel cylinders, covered with Saran plastic on the form of 3-stranded cord. The aerators are thinner, smaller, and weigh only about one-fifth as much as the older types of cylindrical aerators, over which other advantages are claimed.

A valuable and exhaustive summary of the status of mechanical equipment and of the latest developments in the field is published annually in THIS JOURNAL (34). Mechanical equipment in the handling of chlorine is described by the Chlorine Institute (68).

Brown (59) described mechanical sewer cleaners that simplify sewer maintenance, and Seabrook (250) describes mechanical equipment for the making of machine-made joints in bell-and-spigot concrete pipes.

One dozen ways to improve operation of sewage treatment plants, involving the use of mechanical equipment, are described by Simpson (253). The equipment described includes mechanically cleaned racks, grit chamber equipment, sedimentation tank cleaners, and filter dosing devices. Mechanical sludge collectors are discussed by Simpson (253) and in an extensive symposium (23) emphasizing the importance of and the wide interest in the applications and maintenance of such equipment. A prediction of the future status of mechanical equipment, made in a staff article (25), points to the growing importance of mechanical equipment in the field of sewerage.

An elaborate testing program on sewer pipe jointing compounds is described by House and Pomeroy (150). Methods of testing for adhesion, root penetration, and hardness are described and their significance discussed. The five major types of jointing compounds, Portland cement, sulfur-silica, asphalt, coumarone-indene, and coal tar compounds, are scored on four counts. These are: (1) tendency to yield sufficiently to prevent pipe breakage; (2) resistance to deterioration; (3) resistance to roots; (4) ease of making joint. The authors believe the coal tar compounds to be most satisfactory.

The mechanics and design of automatic pH control systems for industrial

waste disposal plants are reported on by Sheen (251), Consideration must be given the following factors: buffer action and slope of neutralization curve, retention time, reaction time, rate and degree of raw liquid characteristics, control point, mixing, sampling, and temperature.

Industrial Wastes

Much activity was noted in 1947 in the field of industrial pollution abatement, probably because of the constant possibility of legislation aimed to control pollution by industrial wastes. There were at least three conferences devoted solely to industrial wastes. In March a conference of Pennsylvania chemists and engineers was held for the purpose of discussing wastes from various industries, as related to the Pennsylvania laws and acts of the State Department of Health; in May, the Third Annual Industrial Wastes Conference was held at Purdue University; in April the most comprehensive symposium ever held in this country was organized by the American Chemical Society, with 23 papers presented on phases of industrial waste production and abatement. In July, the Federation stressed industrial wastes in its annual meeting at San Francisco.

The ASCE scheduled papers on industrial waste subjects in January; the ASME in June; the ASCE in November; and state meetings in Virginia, Michigan, Minnesota and Pennsylvania included papers, or even whole sessions, devoted to industrial waste discussions.

Thus the national and state organizations demonstrated the greatest interest in industrial wastes in their histories and gave an impetus to the consideration of control that is bound to result in great progress.

Chemical manufacturers gave new interest to the activities of the revitalized committee on waste disposal; individual companies openly discussed their treatment plants and publicized results of operation. The pulp and paper research program was expanded. Dairy interests started testing-station investigations. Oil and refinery wastes received new attention. Industry became more conscious of its problems and more tolerant of cooperation with public control agencies.

States such as Virginia, Pennsylvania, West Virginia, Tennessee, New York, Indiana, Illinois, Wisconsin, Michigan and California, expanded their activities aimed at industrial pollution abatement, in some cases changing the name of the state group to include recognition of industrial wastes.

Cooperation of governmental and industrial groups should result in gratifying progress under amicable terms. This will be far better than continuation of legal skirmishes designed to block progress of abatement.

Fermentation

Boruff (53) presented a report on the advantages of centrifuging stillage before evaporation, and gave data on dried grains and solubles, indicating that the process is operated on a profitable basis. Yeast waste evaporation is also profitable for breweries, but winery wastes are still somewhat of a problem. About 1,300,000 lb. of tartrates were recovered from winery wastes in California in 1944.

Spanyer (256) reported on recovery of solubles from thin stillage containing about 4 to 5 per cent solids, half soluble. Evaporators concentrate to 28 to 30 per cent solids, then syrup is dried on steam-heated cylindrical drums such as are used in the milk industry. Capacity is 800 lb. of product per hour and steam consumption is 4.6 lb. per lb. dry solubles produced. Dry solids are scraped off the polished cylinders by knives. Steam pressure of 125 p.s.i. gives a temperature of 353° F. This process is used by the Brown-Forman Distillers Corp. of Louisville.

Klassen and Troemper (172) re-

ported on the recovery plant of the American Distilling Company at Pekin, Illinois. The stillage was filter pressed, the cake containing 67 per cent moisture and the filtrate 2.8 per cent solids. Zaremba quadruple-effect evaporators concentrated solids to 42 per cent, and this syrup was dried with the filter cake to produce a feed. Later the filter presses were abandoned because of expense of operation, including washing and repairing filter cloths. The filters were replaced by screens with 0.002 in. openings. They are followed by rotary presses for the solids, evaporators for the liquid, and steam dryers to produce the dry feed. Condensate from the dryers (barometric condensers) goes to the sewers. Equipment is sufficient for a grind of 16,000 bu. per day. Five Davenport screens and 5 Davenport rotary presses supplant the 20 original 60-plate filter presses.

A feed recovery plant for distillery waste is described by Zack (295). The slop is passed through a vibrating screen, the material retained being compressed in presses. The liquor after concentration in evaporators is mixed with pressed cake and dry grain, and dried in excess. The product is blown into a cyclone unit. The condensate from the evaporators will be treated on high-rate recirculatory rock filters.

Dairy

Trebler and Harding (272) discussed types of dairy wastes and the operation of evaporators. Losses are mostly in wash waters, accidental spills, drips, whey, buttermilk and excess skim milk. Entrainment separators are profitable and necessary for vacuum-pan evaporators. Treatment plants vary in results, largely because of wide variations in load applied. More study is needed to solve problems of operation.

In another paper (273) Trebler and Harding give data on losses, discuss results from a trickling filter plant at Wellington, Ohio, describe an automatic sampler, and review various processes that have been used for dairy wastes. The cost of the Mallory "Oxidized Sludge" process seems high. Digesters for whey must receive whey continuously or they give rise to troubles. The trend is toward high-rate, recirculating filters and away from Imhoff or digestion tanks.

A trickling filter plant for sewage from 1,500 people plus milk wastes from a plant handling 92,000 lb. of milk per day has been installed in Wisconsin by Davy and Noth (77). The plant includes a storage tank for the milk wastes, settling tanks for sewage, and a high-rate filter for the combined sewage and wastes. The loss of milk solids should not exceed 2 per cent, and B.O.D. runs about 1 lb. per 10 lb. of milk lost. Thus the milk losses should give a population equivalent of about 1,100 and the sewage load is from 1,500 people. Various types of recirculation of effluent are available.

The Task Committee on Waste Disposal of the Dairy Industry in 1947 finally received an appropriation for investigations of waste disposal, and set up a testing station at Ovid, Mich., under the direction of E. F. Eldridge. Studies are not yet in progress.

Cannery and Beet Sugar

Disposal of wastes from canneries has been studied by the National Canners Association (282). The operating season is usually rather brief, and long periods between operations allow decomposition of the wastes if stored in lagoons. Such systems are odorous, which has led to the practice of adding sodium nitrate. Many problems are handled by lagoons of several months capacity, with sufficient sodium nitrate dosage to satisfy one-fifth of the B.O.D. The nitrate must be added daily while the pack is in progress. Lagoons must be shallow, 3 to 5 ft. deep, and should hold 1.25 times the waste volume for the season. Eldridge (90) presented a discussion of the cannery waste prob-

lem. About 3,000 canneries in the country operate on a seasonal basis, packing either full line or specialized products. Volume and characteristics depend upon the type of product packed and vary over a wide range. Effective screening should be a common practice. This may be followed by chemical precipitation, sedimentation, biological filtration, or lagooning.

Where storage is impossible, screens and high-rate filters have been used, sometimes preceded by primary treatment aided by addition of flocculation chemicals.

Citrus fruits produce large volumes of solid and liquid wastes (197), of which solids are recovered by drying for cattle feed and liquid wastes discharged back into the ground or diluted in available lakes. Cost of trickling filters is prohibitive. Fermentation with addition of yeast has been tried in Texas.

At Springdale, Arkansas (75), fruit canning wastes equivalent to a population equivalent of 11,000 persons are treated with sewage from 3,500 persons. The plant consists of tanks, filters, and ample flexibility of recirculation. The plant cost $140,000, to which the 5 industries contributed $55,000. Filters are designed to operate at a loading of 1.35 lb. influent B.O.D. per cu.yd. per day. No operating results are reported.

A tomato canning waste treatment plant (201) included screening and lagoons, with effluent pumped over a hill and allowed to percolate down over fields of light and porous soil. The soil is treated with about 2 tons of limestone per acre prior to discharge of 40,000 gal. of waste per acre per week. Lagoons are some distance from dwellings, so odors will not be objectionable if sodium nitrate is used. Any excess nitrate will be of some benefit in the liquor pumped from the lagoons to farm land.

Oeming (208) reports on operation of beet sugar waste disposal plants in which some of the Steffens waste is used for coagulation of flume wastes, giving 60 per cent removal of B.O.D. and 95 per cent removal of suspended solids. Effluent averages about 5 lb. B.O.D. per ton of beets. McDill (195) reports that primary treatment of beet sugar waste is usually not sufficient, while the short campaign makes the use of filters very expensive. Ponding, with addition of sodium nitrate, is in most favor. Coagulation with some of the Steffens waste is only partially effective. Microbiological changes in beet sugar pulp and press waters during the production process are discussed by Allen, Cooper, Cairns and Maxwell (8). Due to favorable temperatures (45° to 55° C.) in the presence of ample nutrients, development of thermophilic bacteria takes place in the recirculated liquid giving rise to acid production and consequent corrosion. To check the development of these organisms chlorine was found to be effective.

According to Brandon (54), the sedimentation and reuse of transport water from beet sugar washing offer no difficulty. The polluting character of process water can be reduced by as much as 50 per cent by chemical treatment, and 80 per cent by biological methods. The recirculation of the process water after the addition of chlorine or sulfur dioxide is recommended for bacterial control.

Dickinson (79) reported on the properties and treatment of waste waters produced from potato canning. Approximately 30 per cent of the weight of raw potato enters the waste water. Screening will remove a considerable portion of this waste (5 to 40 per cent). Settling for 1 hour removes 60 per cent of the solids from the screened waste giving a sludge volume of 8 per cent. The addition of lime to the potato waste prevented the sludge from rising. The sludge drains slowly and disposal is difficult.

The settled waste has a B.O.D. of 2,300 p.p.m. The biochemical oxida-

tion rate of the waste departs from the normal logarithmic value.

Dickinson (80) further reported on results of pilot plant treatment of vegetable cannery wastes. The treatment consists of sedimentation and biological filtration with recirculation. The results obtained under various conditions with waste waters from carrots, beets, dried beans, potatoes, rhubarb, and spinach are given. The application rate was 10 to 14 gal. per cu. yd. per day.

Packinghouse and Wool Pulling

The losses per ton of kill were reported by Mohlman (202) based on some 14 surveys. Overall national loads were estimated; also examples were given of excessive losses. Several stages of trickling filters, including washable roughing filters, seem to be most effective on packinghouse wastes. Chemical treatment is used at Austin, Minn.; also activated sludge, if the waste is diluted by sufficient sewage.

Construction and operation of small filters for treatment of slaughterhouse wastes is described by the West Virginia Water Commission (36). Recovery of grease, blood, and fleshings inside the plant can be greatly improved.

Wool-scouring wastes are recovered at Bradford, England (45), according to Beedham, at considerable profit. The character of wastes (plus sewage) is changing, however, owing to larger use of nonsoap detergents, which are not amenable to acid precipitation. The recoveries of wool grease have not been reduced appreciably, however, and the sales largely offset the total cost of the works. Some 53 acres of trickling filters, with coal as the filtering media, are becoming overloaded, so a high-rate filter was investigated as a pretreatment device. Results were encouraging and such filters may be installed in the full-size plant to extend the life of the filters.

Use of hypochlorite for treatment of wool-scouring wastes is discussed by Faber (96), who suggests the use of chlorine, possibly from calcium hypochlorite. It is claimed that 98 per cent of the grease can be recovered and a clear effluent discharged. About 70 to 75 per cent of the grease can be removed from the filtered sludge and sold. Enormous amounts of calcium hypochlorite are required, the amount of chlorine required being approximately equal to the amount of alkali used in the scouring operation. Although the process was installed at the Abbott Worsted Company mill at Forge Village, Mass., operating results are not given. Further data are desirable.

A bulletin by Eldridge (91) covers characteristics of wastes from slaughter and packing houses, salvage, grease collection, and treatment by various means.

Two French articles (56) (88) describe systems of complete treatment involving settling, chemical coagulation, trickling filters, and digestion.

Planchon (215) discusses slaughterhouse waste characteristics and treatment in France. The waste from 1 steer or 2 hogs is equivalent to sewage from 70 to 100 persons. Minimum treatment is settling and chemical treatment. Complete treatment included trickling filters or activated sludge.

Pulp and Paper

Gehm (105) reviews the problems of the pulp and paper industries. Changing of the base from calcium to magnesium would eliminate most of the wastes from the sulfite process, but this is too expensive for mills. Tests are being made on fodder yeast from sulfite wastes, but this also appears expensive and not a complete reduction of pollution. Storage of wastes from kraft and soda processes greatly reduces B.O.D. Most hopeful prospects visualize reuse inside the mill of products recovered from former wastes.

Use of the B.O.D. test for pulp wastes

is criticized by Gehm and discussed by Weston (106), but they conclude that it is the most valuable test with reference to disposal and urge that the technique of the determination be improved.

The industrial alcohol plant (from sulfite waste liquor) of the Ontario Paper Company at Thorold, Ontario, was described by Joseph (161). The plant produces 225,000 gal. of sulfite waste liquor per day, containing about 34,000 lb. fermentable sugars. Sulfur dioxide is first removed by steam in a stripping column, then cooled to 90° F., neutralized with lime to pH 5.5 to 6.0, yeast added and allowed to ferment for 12 to 14 hours. The weak 5 per cent alcohol "beer" is rectified in a column still to 96 per cent strength. About 1,800 Imp. gal. alcohol are produced per day. B.O.D. reduction, however, is only around 40 to 50 per cent.

Fodder yeast from sulfite waste liquor was discussed by Tyler (274). The reduction of B.O.D. was estimated around 50 to 60 per cent, but economic limitations restrict any contemplated use of this process.

Reduction of pollution of the Clarion River, in Pennsylvania, is described by Siebert (252). The New York and Pennsylvania Company discharge wastes at Johnsonburg from manufacture of sulfite and soda pulp, de-inking, and white water from paper machines. The sulfite waste liquor is evaporated to a thick syrup, known as "Clarion Extract," and used for adhesives, roadbinder, and various other purposes. The soda wastes are negligible; de-inking wastes are pumped to a pond 375 ft. above the mill, held for many weeks, and then allowed to cascade down a ravine to the Clarion River. The B.O.D. appears to be reduced about 50 per cent. Paper wastes are screened and reused. A coagulation and settling basin is to be installed. Finally, all effluents, plus wash water, are to be settled in a basin 140 ft. long by 35 ft. wide by 12 ft deep before discharge to the river. These combined efforts to lessen the plant pollution have been taken in cooperation with the Pennsylvania Sanitary Water Board.

Sulfate, kraft, paper mill and wash waters are lagooned at the plant of the Camp Mgr. Co. at Franklin, Virginia (74), resulting in about 22 per cent reduction of B.O.D. in 1945. Later, wastes from the evaporation process were passed through the lagoon. The overall reduction of B.O.D. was 60 per cent (for the volume ponded). At present the ponded fraction is only 12.5 per cent of total flow, but contains 60 per cent of the B.O.D. The small flow can be held through the period of low river flow and released later, thus improving river conditions during the critical period.

Strawboard wastes have been studied by Bloodgood (50). Chemical analyses indicate a deficiency of nitrogen. The Gooch crucible filter gave much higher suspended solids than by use of filter paper. B.O.D. was reduced 80 per cent in samples incubated at 37° C. for 14 days. The rate of reduction in mixtures with sewage was more rapid than in either sewage or waste alone.

De-inking wastes were discussed at length by Hodge (144), including results of many laboratory studies of clarification by chemicals made by Miss H. G. Swope. No results were given for plants actually in operation.

Warrick (281) published excellent data for losses from various Wisconsin pulp and paper mills.

The production of fodder yeast from sulfite waste liquor in a special pilot fermentor is described by Harris, *et al.* (125). The rate of yeast growth with various sulfite liquors is compared with the rate of growth in sugar solutions produced by the hydrolysis of wood. The novel aerobic fermentor has good foam control properties and its operation is more fully discussed by Saeman (237). The device originally developed in Germany is characterized by an arrangement for mechanically dis-

persing air and forcing circulation through a central tube. Cost figures are not given, but Rosten (227) discusses the economics of dry food-yeast production in the U. S. He states that it will cost about 4 cents per lb. with a yield of 40 to 50 per cent of reducing sugars and suggests a flow sheet simplifying German practices.

Variations and similarities of paperboard mill white water are given by Rudolfs and Axe (236) in a survey of 8 paperboard and 3 specialty mill wastes. Quality of raw material and mill operating procedures have pronounced effects on the character of the wastes. Data are presented showing the volume and concentrations of the wastes, their effect on B.O.D., and the efficiency of recovery equipment.

Pharmaceutical

Many problems are presented in disposal of wastes from new processes of manufacture of antibiotics. Knoedler and Babcock (173), of the Lederle Laboratories, reported on wastes from penicillin, riboflavin, and biologicals. Their suggestions are that such wastes be evaporated to a dry powder. Obviously, this is very expensive.

Starch

Bottling-up of starch wastes was described by Hatfield and Greenfield (117). Evaporation of steepwater and sale as feed was the largest factor in the reduction of B.O.D.

Organic Chemicals

The Manufacturing Chemists' Association has organized an active committee on pollution under chairmanship of R. W. Hess. He has published a comprehensive bibliography (139) on chemical wastes, from 1937 to date. Harlow and Powers (124) described the extensive waste disposal plant of the Dow Company, which handles mainly phenol-containing liquors.

Tanning

Sutherland (262), gave a review of tannery wastes. He states that in 1941 some 28 tannery waste plants were using plain sedimentation, with or without chemicals, but no secondary treatment was in operation.

Reuning (224) describes the treatment of tannery waste by mechanical flocculation, sedimentation, flow equalization, and sludge dewatering by centrifuge. The spent tan liquors are evaporated for recovery. The suspended solids are reduced from 2,500 p.p.m. down to 250 p.p.m., and the B.O.D. from 600 p.p.m. down to 350 p.p.m. The moisture content of the centrifuge sludge is 85 per cent and the volume is 10 per cent of the settled sludge.

Textile

Geyer (108) discussed textile wastes and showed design of two small settling-tank plants as well as the mixed waste sewage activated sludge plant at Greensboro, N. C.

Coke and Gas

Disposal of byproducts coke plant waste was reviewed by Gollmar (113). Extraction and vapor recovery processes are in wide use, but no biological process is in use in the U. S. Admixture of less than 0.5 per cent with sewage can be handled by activated sludge treatment.

Pickle Liquor

Hoak (143) reviewed the many processes that have been studied by the American Iron and Steel Institute at Mellon Institute. It is claimed to be feasible to convert pickle liquor to ferric chloride and sodium sulfate, but apparently no plant has undertaken this recovery. A study on use of dolomitic lime for neutralization of pickle liquor was also published by Hoak (142).

A curious article in the trade journal of the steel industry (117) claimed that sewage is responsible for 90 per cent of river pollution, and industrial wastes 10 per cent; that pickle wastes can be neutralized, or that acid plus iron oxide can be recovered; and that by these expedients the steel industry had taken itself pretty well out of the stream pollution picture. The writer went on to say that rivers again will be clean when municipalities decide to catch up with progressive industry in pollution abatement.

Mine Drainage

Mine drainage is being actively attacked in Pennsylvania. Hoffert (145) described the technique of mine sealing.

Plating and Cyanides

Barnes (40) describes the recovery plant at Meadville, Pa., built for the Talon Company. Haseltine (134) compared methods of destroying cyanides and gave a method of determination.

A study is being undertaken by Dodge (84) to determine the possibility of using ion exchange materials as a means of concentrating dilute wastes from trickling of brass.

A review of wastes from brass and copper industries is given by Wise, Dodge, and Bliss (293) on the basis of experiences in Connecticut. In one plant 90 per cent of the pollution load was derived from the dilute wastes or rinse waters. Treatment methods developed in the past by the Chemical Engineering Department of Yale University are outlined.

Kenosha experiences with the effect of copper-bearing wastes on the digestion of sludge are described by Rudgal (230). Copper content of 0.25 to 0.38 per cent on dry solids basis did not materially affect gas production.

Dobson (82) stated that cyanide can be eliminated by the addition of 4 p.p.m. of chlorine per part of cyanide (CN) at controlled pH values above 8.5.

Refinery

There was considerable interest in refinery wastes in 1947, largely stimulated by Hart's series of articles, later published in book form (126), and various discussions by Weston (285). Millions of dollars were spent on oil-skimming basins (A.P.I.), largely by the refineries in the Calumet District in Indiana. This progessive spirit was stimulated by the suit brought by Illinois against Indiana for abatement of pollution of Lake Michigan. The response of the oil industries was probably the outstanding development of the year in industrial waste abatement.

Rubber

The review of the status of wastes arising from rubber industries was presented by Hebbard, Powell, and Rostenbach (136) in the Industrial Waste Symposium of the American Chemical Society. Methods of recovery of partially or wholly processed materials from waste waters as well as treatment facilities now installed are described. Ruchhoft, Placak, and De Martini (229) reviewed the work done in Cincinnati in conjunction with the problems arising from the manufacture of large quantities of synthetic rubber during the war. The objectionable characteristics of these wastes are due to their B.O.D. and taste and odor producing constituents. The wastes were amenable to biological treatment by the activated sludge and trickling filter processes.

Flax Retting

Ordinarily, flax retting is done by batch process with the leach ret liquor and wash waters containing high concentrations of pollutional materials being discarded. The combined wastes have a B.O.D. of 1,140 p.p.m. according to Brandon and Taylor (55), who worked in England during the war to reduce the pollution from this source. Treatment of these wastes by trickling

filters and coagulants was not considered suitable. The objective selected was the reuse of the waste liquor in the process. Finally a process was developed whereby the retting was done under aerobic conditions with diffused air. By this method 40 successive batches of flax were retted without discharge of retted liquor. Under aerobic conditions the concentration of acid intermediate products was reduced and the B.O.D. of the ret liquor consequently did not increase beyond 2,000 to 7,000 p.p.m. with successive uses. The liquor used repeatedly would have to be disposed of at the end of the season.

The fundamental investigations in the biochemistry and microbiology of retting process, which led up to the development of the new retting process described above, are presented by Allen (4) (5) and by Allen and Eden (6) (7). The general bacterial flora was found to be similar in the different processes of flax retting, consisting of coliforms, streptococci, and spore-forming anaerobes. The continuous aeration of the retting liquor during the course of a ret encouraged the growth of aerobic and facultative bacteria without affecting the numbers of anaerobes.

Acids were produced in the anaerobic retting process, but the liquor became alkaline when the retting liquor was aerated. The polluting strength of the liquor was reduced as a result of aeration.

Miscellaneous

Neutralization of acid industrial wastes is discussed in detail by Jacobs (158). He found acid strength to be of little consequence with hydrochloric and nitric acids, but with sulfuric acid the strength should not exceed 0.5 per cent. High-calcium limestone beds are recommended for all three acids, provided strength limitations are observed and the waste is free of suspended matter. A bed of stone 5 ft. in depth can be used for 0.5 per cent sulfuric acid at rates of 0.5 to 1.0 gal. per min. per sq. ft. of bed area. pH control is not suitable for use with limestone. For accurate automatic pH control, high-calcium hydrated lime with a retention time of 2 min. or dolomitic hydrate with a retention of 5 to 10 min. is recommended.

Studies on the treatment of shell-filling wastes are reported by Wilkinson (289). Wastes are derived from laundering of contaminated clothing; washing of tools, floors, etc.; and washing out rejected shells. The total volume of wastes and sewage averaged 11 to 20 gal. per employee per day. Average strength of the waste varied from 155 to 278 p.p.m. B.O.D. Wastes were successfully treated on trickling filters dosed at 77 to 112 gal. per cu. yd. per day. Trinitrotoluene in concentrations to 60 p.p.m. had little or no effect on sludge digestion.

The treatment of wastes containing cutting oils and floor washings from aircraft factories was described by Hogg, Pettet, and Collett (146). The treatment consisted of breaking the emulsions by chemicals, such as alum, alumino ferric, ferric chloride, and lime. The most satisfactory treatment was obtained with a neutral emulsion.

Processes which produce wastes from the washing of coal and steps being taken to eliminate stream pollution from this source are described by Parton (211). Methods and steps taken to alleviate the problem include: (*a*) settling and impounding facilities for the removal of fine coal from the wash water; (*b*) promotion of new uses for the fine coal so recovered and development of a froth-flotation method for beneficiating the waste solids; (*c*) dredging operations to remove coal already settled in river bottoms.

A new solvent for the recovery of phenols from industrial wastes is described (207). Consisting of an insoluble mixture of higher aliphatic alcohols and, up to 85 per cent, butyl

acetate, the material is called Phenolsolvan. Ninety-nine per cent recovery of certain phenols is claimed. The Phenolsolvan is almost completely recovered by distillation. A method of recovering extracting agents used in recovering phenolic compounds is described in a patient (81).

Biological treatment of a largely soluble organic waste from chewing gum manufacture has been described (189). Wastes having an average B.O.D. of 3,800 p.p.m. were treated by a combination of digestion and sand filters. Ten-day digestion was used; filter loadings up to 160 lb. of B.O.D. per acre per day were used. Massive doses of chlorine were required to reduce color to a satisfactory value.

Stream Pollution

Abatement and Control

An abundance of discussion of stream pollution abatement and control problems appeared during the year. The abatement literature may be subdivided into the discussion of local problems, discussion of the general problem, state- and compact-level programs, and possible federal legislation in this field.

Snyder (255) discussed the effect of strip mining upon stream pollution and showed that although delayed for some months the pollution as determined by sulfate and free acidity is proportional to the area stripped. From a legal study of strip-mining pollution cases, Beck (43) concluded that additional measures against such pollution are needed. Murdock (205) reported on the methods of study used in strip-mining pollution cases and recommended that there was a need for greater control over watersheds serving as a source of water supply. Hoffert (120) stressed the magnitude of stream pollution problems resulting from acid mine drainage, stated that mine sealing was the only control technique, and reviewed research projects resulting from this problem.

Hart (127) (128) (129) (130) (131) (132) presented a series of papers discussing measures that should be applied by oil refineries in waste disposal anti-pollution programs. The prevention of pollution caused by discharge of cutting oils from manufacturing plants was discussed by Hogg, Pettet and Collett (146). In Maine, the Supreme Court (9) decreed that the polluters be permitted to discharge certain quantities of waste sulfite liquor based upon the maintenance of a predetermined quality of water in the stream. According to this ruling the companies involved must maintain weekly sampling and analysis of the Androscoggin River at stated points to permit the determination of the controlled discharge with reference to the production of obnoxious odors; and maximum limits are placed on the quantity of waste discharged per week during specified periods of the year.

Laboon (180) stated that 102 of 127 communities in Allegheny County, Pa., have been ordered to stop discharging untreated sewage into the streams. Seventy-seven of these communities and 21 out of 90 industries are participating in the Allegheny County Sanitary Authority program. The Authority has completed the first phase of its study with measurements on 33 main sewer outlets and is now checking industrial wastes from 2,000 plants. Philadelphia (21) reduces the B.O.D. of its 300 m.g.d. of sewage only 6 per cent before discharge into the Schuylkill and Delaware Rivers. A minimum of 75 per cent B.O.D. reduction is needed at Philadelphia and an abatement program which includes the construction of two new plants and the expansion and improvement of the present Northeast treatment plant is planned.

Pickett (212) and Doll (85) both discussed the problem of the protection of ground water supplies from sewage and industrial waste discharges in Los Angeles county. It was pointed out

that the industrial wastes discharged into a subsurface river or water basin travel in a more or less narrow band and do not diffuse through the body of water as in surface supplies; consequently, less effective dilution is obtained. Both authors cited an incident where 11 wells serving 25,000 people were put out of commission by the discharge of a small amount of industrial waste 15 miles away. Although the industrial plant was closed after a few days of operation, treatment of the water from these wells to make it potable is still required 2 years after the incident. The authors suggested legislation to be enforced by local political subdivisions.

Cohn (70), discussing stream pollution abatement, suggested that progress on the problem can be obtained by educating the people to an understanding of the hazards of pollution, by a program whose objective would be the preservation of the quality of water consistent with use of the stream, and by the cooperation of industry and local government.

LaDue (182), speaking from the standpoint of the water works profession, suggested that the problem will be solved by the development of an understanding by all groups of the need for abatement, which will culminate in the acceptance of local responsibility. On the other hand, Hedgepeth (137) presented a discussion of abatement from the standpoint of the practical industrialist and suggested that the problem can be solved if sold to management on a "must" basis and if the industrialists are permitted a reasonable use of the assimilative capacities of the stream.

In California (35), the House created a fact finding committee for study of the problems of water pollution in surface and subsurface streams and coastal waters. In the Delaware basin, Allen (3) discussed the function of the Commission and Beckett (44) reviewed the status of abatement projects, citing progress on treatment facilities in 47 municipalities, including Philadelphia and Camden. In Florida the abatement situation is not very encouraging according to Lee and Patterson (186). Only 12 per cent of the state's urban population is connected to modern sewage treatment facilities, and, as a direct result of pollution, 232 sq. miles of commercial shellfish beds had to be condemned. Progress on abatement of industrial pollution on the Illinois River due to discharge of wastes from distillation residues was reported by Klassen (171). Activities of the Indiana Stream Control Commission, according to Holtje (149), resulted in plans for 82 new sewage treatment plants. With these additions, all cities over 30,000 and 95 per cent of the urban population in the state will have sewage treatment facilities. In contrast to the above, Covert (72) (73) reported that little progress was being made in abatement in Mississippi, and that the industries responsible for pollution included paper and pulpwood, fertilizer plants, cotton mills (contributing dyes), starch plants, creameries, and oil fields.

In New York state a joint legislative committee has completed an extensive study and reported (20) that pollution damage costs the state $14,000,000 annually. Eighty per cent of urban water supplies are obtained from surface sources that are subject to sewage and waste pollution. Some are very seriously affected. The pollution has also seriously affected commercial fishing and recreational facilities, and the committee pointed out that New York is faced with the most serious sewage and waste problem. The city of Peekskill has been given an order by the Interstate Sanitation Commission to prepare plans for the correction of its pollution to the Hudson River (18).

The Pennsylvania State Sanitary Water Board (28) has issued 4,126 pollution abatement orders and on the basis of this activity has surpassed all

other states in its antipollution program. An improvement in the Clarion River in Pennsylvania was reported by Siebert (252) as a result of the reduction in pollution of wastes by the New York and Pennsylvania Paper Company. In Tennessee, Farrell (99) reported that of 15,000 miles of streams, 710 miles are seriously polluted, and, in addition, 850 miles are unsuited for many uses. A Tennessee Stream Pollution Control Board was appointed in 1945 and its control program has been integrated with the T.V.A. Stromquist (261) described the cooperation given by the T. V. A., to local authorities and certain paper mills in the prevention of stream pollution. In Puerto Rico, sewage and distillery waste presents a serious stream pollution problem, according to Figueroa (100).

Berry (48) reported that, although surface waters are plentiful in Ontario and other parts of Canada, industrial activity has increased and sewage treatment has not kept pace, and since consumers demand high standards of quality, consideration of pollution prevention is imperative. Clay (69) reported on pollution problems of the Tame River basin which drains the highly industrialized areas of Birmingham and which is regarded as one of the most seriously polluted rivers in England. The high dissolved oxygen content of this river at the Birmingham boundary does not indicate recovery, for the river is biologically sterile because of industrial wastes and is incapable of sustaining fish, being referred to as "The Lifeless Tame."

The report of the Water Pollution Research Board, Department of Scientific and Industrial Research (England) (283), stresses the importance of consultation of the laboratory by industrial firms before a new factory is built or a new process is undertaken. The work of the laboratory is concerned with matters affecting the purity of surface and underground waters and includes research on the treatment of sewage and industrial wastes, and on the effects of polluting substances when discharged into streams or lakes. In England (30), 1,600 local authorities are responsible for enforcement of antipollution laws. Since this mosaic is not working satisfactorily, a bill adopting the recommendations of the Milne Committee which would set up 29 River Boards is to be introduced in the next session of Parliament.

Federal Pollution Abatement Legislation

Mundt (204) cited the need for federal legislation which would provide for proper enforcement, prohibit new sources of pollution, and establish standards, the need being the result of the failure of voluntary control and the inadequacy of state laws on account of the interstate nature of pollution. The legal responsibilities of the states and the federal government were reviewed by Wolman (294), with a summary of the administrative machinery and regulatory powers of each. Wolman cited examples of current state procedures, defects in state practices, and possible legal, fiscal, and administrative solutions. He suggested further development and trial of interstate compacts and sanitary authorities. The abatement of industrial waste pollution was discussed by Powell (216) who cited cost of treatment facilities, lack of fundamental data, and confusion as to standards, legal measures, and measures of control as causes of failure in the industrial waste treatment field. He emphasized the need for basic research and stressed the desirability of intelligent planning and cooperation between industry and control agencies. Parran (210) recognized the interests and responsibilities of all and explained the interest of the U. S. Public Health Service in federal legislation dealing with pollution control that provided for: (1) a federal agency to act as coordinator and advisor; (2) authorization of funds to carry on the

work; (3) an advisory board to the agency; (4) permission for states to form compacts; (5) promotion, investigation, and research; (6) grants-in-aid or loans to civil subdivisions and persons for treatment projects; (7) continuing interest by the federal authority in efficient operation of completed projects.

Scott (249) reported that 42 states had pollution control agencies with 4 principal patterns in agency control responsibilities, and 6 states had no control agencies. In the largest group, 17 states, the control responsibilities were shared by the State Board of Health and another agency. He also reviewed interstate compact legislation and federal legislation, which contained provisions similar to those enumerated by Parran. Scott concluded that the problem has grown beyond state borders and that the principal service the federal government could render would be to promote, coordinate and carry out research in the field of sewage and industrial waste treatment.

LeBosquet (185) reviewed the bills introduced into the 80th Congress and abstracted S418 as amended. S418, as amended, eliminated the 33⅓ per cent grants-in-aid provision and contained the "Residual Federal Control Clause" which was designed to gain support from all groups favoring any federal legislation. This provision in S418, as amended, requires state permission before federal action can be effective. The New Jersey Health Department (33) approved the provision for the investigation of stream pollution by the U. S. Public Health Service in cooperation with state, interstate, and local authorities, but opposed provision for federal court action and urged disapproval of S418, or its amendment, so that intrastate and interstate streams on which two or more states are prosecuting abatement programs would be excluded from its provisions. The Board of Directors of the American Water Works Association presented (32) a 6-point policy statement favoring limited federal legislation which uses to greatest extent existing facilities, designates U.S.P.H.S. as administrative agency, provides for classification of waters by cooperation of state and U.S.P.H.S., and provides for an Advisory Board. The board does not favor grants-in-aid and opposes federal court action. A new federal pollution control bill (26) provides that the Federal Works Agency handle the construction phases of pollution control projects. From the review of the pollution abatement literature it must be concluded that the problem is extremely complicated and that its solution will require the cooperative effort of many groups on the legal, fiscal, administrative, engineering, and scientific research phases of this problem.

Biology

Dobson (83) found that the CN radical in concentrations as low as .025 p.p.m. is toxic to fish. A stream may not show pollution from a chemical standpoint but, as Butcher (62) points out, toxic ions such as copper may be present which affect the biological life. He also lists four zones of pollution: (*a*) foul pollution where only sewage fungi and few tubicids can exist; (*b*) zone where a small amount of algae grows and tubicids and sewage fungi are abundant; (*c*) mild pollution where varied organisms such as waterlog louse and algae can exist; (*d*) the repurified zone containing an abundant and varied fauna and flora. Covert (72) (73) also stresses the fact that, as the pollutional load on a stream decreases, biological life increases. Hart (132) (133) discusses the effect on fish life of oil-in-water, water-in-oil, acids, and alkalies, and states that hydrogen sulfide, mercaptan, phenolics, and pyridine are especially toxic to fish life.

Hall (121) states that dense algal growths may be detrimental to fish life. He also maintains that a wide variation

in the CO_2 content may cause a high mortality in certain species of fish.

Nuisances from excessive algal growths in Madison Lakes in Wisconsin were attributed by Sawyer (238) to the fertilization by highly treated biological effluents which still contain nitrogen and phosphorus in soluble forms. By contrast, the fertilization by agricultural drainage was not considered as important.

Bacteriology

Chapman (67) uses selective media containing tergitol-7 and bromthymol blue in the differentiation of the coliform group. *Esch. coli* produces yellow colonies with yellow zones while *A. aerogenes* gives yellow "gum drop" colonies which are larger than *E. coli* and are surrounded by yellow zones. Para-coli and other lactose nonfermenters give colonies surrounded by blue zones. Counts run 30 per cent higher than other selective media.

Hannay (122) studied the bacterial flora of the river Avon in England. Below the outfall fecal streptococci decreased by 97 per cent in less than 3 mi., and below another outfall by 97.4 per cent in 1.9 miles.

Self-Purification Characteristics

Reinhold (223) presented a simplified method for evaluating load tolerances on the basis of the Fair-Imhoff calculations. Velz (276) presented an extended mathematical consideration of various factors involved in self-purification of streams, considering in detail the calculation of the effect of these factors, and using the more-or-less established constants as the basis for the treatment presented.

The accepted constants used in calculation of stream characteristics have been given reexamination, and there appears to be ample reason for doubting the constancy of some of these "constants." Abbott (1) has found that there is a wide distribution of the deoxygenation constant "*K*" in the equation $d\,x_T/d\,T = K\,(L - X_T)$ commonly used to express biological oxidation rates. Twenty degree constants ("*K*") reported vary from 0.075 to 0.30 in a continuous pattern, as compared to the accepted constant of 0.1. Abbott reports further that there is no sharp demarcation line between carbonaceous and nitrogenous oxidation, as required by the classical theory.

Kittrell and Kochtitzky (170) made a detailed combined laboratory and field study of self-purification of a shallow turbulent stream. The 20° deoxygenation constant "*K*" based on laboratory tests showed progressive decrease on samples taken successively farther downstream below the source of pollution, after a maximum was reached. The maximum was 0.34, with continuous decrease to 0.095 being noted. Calculated reoxygenation rates for physically similar stretches of stream showed enormous variation.

The authors suggest that the very high rates of self-purification noted might be caused by removal of B.O.D. from the stream by deposition or adsorption on bottom slimes, followed by anaerobic decomposition.

Wiley, *et al.* (288), presented a discussion of the results obtained by mechanical reaeration applied to a stream below a paper mill at a point where a serious oxygen depletion occurred. Marked improvement of the zone of recovery is reported.

A study of five natural streams by Veale (275) showed that the effect of dairy waste was dependent upon the amount of dilution, the type of stream bed, the rate of stream flow, and the oxygenation of the water.

Stream Standards

The Interstate Commission on the Potomac River Basin (155) adopted minimum water quality criteria for the streams of the Potomac River Basin to serve as a guide for a sanitary survey.

Four classes of waters are set up,

varying from Class A, suitable for drinking water with no treatment except chlorination, to Class D, intended to exclude nuisance conditions.

Goudey (114) proposes classification of ground waters into 4 groups in relation to their usefulness for domestic, irrigational, and industrial purposes. Few authorities will agree with the author that water containing up to 5 p.p.m. of phenol is suitable for a domestic water supply.

Wiley and Howland (287) favor the application of minimal stream standards, with the establishment of standards of stream sanitation above the minimum, where the maintenance of such standards can be justified on an economic basis.

A rational method for computing the safe amount of storm water diversion in combined sewerage systems is proposed by Theroux and Meek (266). By knowing the B.O.D. of the storm sewage and by using the computed oxygen deficit of the stream as the criteria, the allowable percentage of diverted storm sewage is determined.

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Industrial Wastes

WASTE TREATMENT PROBLEMS FROM THE VIEWPOINT OF INDUSTRY *

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There can be no question that the waste treatment problems of industry are numerous, or that industry has been doing a lot of thinking about them. Just because they are so numerous, it will be impossible to concentrate discussion on any one, or even any few of them. The problems also vary widely, just as industrial wastes vary widely with respect to their characteristics. And not only are the problems concerned with what wastes require treatment, how they should be treated, and how far the treatment should be carried, but also with what materials to use, how to obtain materials, room for installation, manpower, correlation with other activities, and last, but not least, financing the treatment installations. That presents a rather formidable list of problem categories. Therefore, this discussion well can be kept rather general.

Background of the Problem

It may be of interest to examine the background of these problems—to find out just why they are problems. The answer to at least one aspect of this question is rather obvious. They have been precipitated by a relatively sudden demand for their solution.

The conditions which must be corrected have been extant for a long time. Everybody knew that these conditions existed, but nobody did much of anything about it. Industry did not do anything, municipalities did not do anything, state agencies did little other than enact legislation, usually without funds to administer it, and the federal government did most of what was done by supplying funds for the installation of plants to treat domestic sewage. There has been a lot of criticism of this latter practice, but it got a lot of sewage treated. Little in the way of industrial waste treatment was provided for in this manner—not enough, all told, to make even a ripple on the surface of existing pollution conditions.

Then came World War II, and the conditions which were bad enough before the war became much worse. Then came the atomic bomb, and the war was over. Then came the deluge—the country-wide enactment of antipollution legislation, which in many cases was accompanied by appropriations for administration. This gave rise to the problems—right along with the problems of reconversion, readjustment, jockeying for postwar markets, labor strife, and material shortages.

The Pennsylvania program is a typical, localized example. It is little wonder that many industrialists regarded the whole thing, at first appraisal, as one grand headache—something they did not deserve after all they had done to win the war—a sort of persecution.

Now just why were these matters such seemingly *insoluble* problems? Well, for one reason they were com-

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pletely new. The industrial establishment had been producing wastes for perhaps a hundred or more years, and had been discharging them into the most convenient nearby surface waters. The wastes had been polluting the streams in increasingly greater degree until the waters today perhaps are of little value as a resource.

But nobody said anything about it —nobody did anything about it. The establishment was busy expanding the variety of its products, extending its markets, and increasing its production. Least of all was it giving any thought to its wastes. Consequently it knew little or nothing about their quantity, their quality, how they affected the surface waters, or what inconvenience or damage they might be causing others. When they were required to know about these things, and to correct them, they had a problem on their hands.

Survey Procedure

The first phase of the problem concerned the study of the wastes and how to make a practical survey. The establishment never had done, or heard of anything like that before. Could they do it with their own personnel? They had done a lot of other things so they would try it. Right here entered one of the very critical situations which the abrupt requirement for waste treatment has developed. Surveys often have been too superficial, and there is ever present the possibility that a more or less standard piece of equipment which *apparently* is suitable will not treat the waste adequately. It is not improbable that there will be some disappointments.

Other establishments reacted differently. These establishments decided to look for help outside, and to retain consultants. But not many people in industry had retained consultants for industrial waste treatment and disposal over the years, and there was rather a dearth of experience.

Lots of experience and ability in water and sewage treatment were available. But it is a "far cry" from water and sewage to industrial waste treatment, and a "farther cry" from the way in which things are done by municipalities to the ways of industry. As a result, when proposals were received, showing costs and functions in terms totally unknown to industrial management, another problem was presented. What did it all mean? Efforts to explain the type and extent of treatment often only added to the confusion.

Reaction to Pennsylvania Program

When it was realized that not only would there be a capital investment, but also operation cost, the resentment increased in many instances. Also the question was raised as to the degree of purity such an expensive plant surely would provide. Was this extreme degree of purity necessary? This question often was asked even without knowledge of the purity required, or good understanding of the terms used to define it.

All these reactions and more could be noted among industrial people in the early days of the Pennsylvania Stream Clearance Program. There was a great deal of discussion, and the question, "What are you people going to do?" was asked on almost numberless occasions. Some industrial organizations had seen the program coming and had been studying their plants and preparing. These organizations were waiting to learn, and needed to know only what form the program would take. They were prepared for almost any development and required only authoritative demand to go into intense activity. Others were not so fortunate, and with these the confusion and resentment usually were greatest.

The various conditions and reactions as related to industry, naturally were most pronounced immediately after

the program was started about two years ago. There followed a period of criticism and question by industry which was concurrent with a not-too-well-defined position on the part of the state. This might be termed the formulative and criticism period, during which industry was divided into three general groups. One group set as its policy a complete cooperation with the state in an effort to correct pollution. A second group was made up of those who were not too sure that the program would hold up—that it would not fall under its own weight. If the program were maintained, they would go along—more or less willingly. The third group consisted of those who felt they were being persecuted—would do nothing they were not made to do—and who continually talked of complete failure of the program, perhaps on the basis of "misery loves company," with total disregard for any rights of others.

The period of program formulation and criticism moved on. Its termination well could be marked with the adjournment of the last Legislature. The program had not been weakened. It emerged stronger than before—both in its composition, its aims, and in its administrative personnel. The three groups in industry became, in general, only two. The first and second largely had merged; the third still exists, but reduced in size, and it is not so vociferous.

So far in this discussion, little has been said about waste disposal problems from the viewpoint of industry, and little can be said in the way of generalization. The thoughts of industry are as diversified as are the problems with which they are concerned. But industrial people, from training and general surroundings, are accustomed to organizing their thoughts along lines of getting the greatest return for the least effort and expenditure. Now that there is general understanding of the stability of the Pennsylvania Stream Clearance Program, some industrial people are giving very serious thought to the whole matter and to what they will have to do. Naturally, these thoughts are concerned with costs—with doing a satisfactory job for the least cost—and the various considerations have, to some extent at least, crystallized along certain matters of policy under which details of design for treatment of wastes and operation of treatment plants can be worked out most advantageously.

Stability of Pollution Control Program

Perhaps the first item to consider is the question, "Is the program something which can be regarded as permanent or will it gradually fold up?" This question has been asked by a number of industrial people.

Examination of the circumstances surrounding the program can be summarized to some extent. The political phases cannot be ignored and in this connection the program is bipartisan. The 1937 Act was put through by a Democratic administration; the 1945 and 1946 amendments and appropriations by a Republican administration. In neither instance was there concerted political assault. Instead, the program seems to be popular politically.

The program has been variously active and before the people for about two years—time enough for any political pressure in favor of this or that to show itself. There has been opposition it is true, but the program to date is "batting 1,000."

What of the future? It is reasonable to assume that even the most indifferent people would rather have an attractive stream running past their doors than a dirty ditch. Therefore, it would seem that the program will have increasing popular appeal. What will people do with all the leisure that is to be theirs in the modern scheme?

A lot of it will be spent in the open, and those who can afford perhaps only a single trolley fare have a right to recreation which nature has placed relatively close by, the same as those who can charter a luxury plane for a trip to the Canadian Rockies. This, again, is not a factor which points to an early demise of the program. The orgainzation and the administrative personnel which has been established for the program, also are indicative of continued effort. Most of industry has accepted the facts set forth in this survey as indicative of continued activity with perhaps more effort directed at greater stream cleanliness.

Design Requirements

Not infrequently, industrial people have voiced the idea that the state should develop waste treatment methods for industry to use. This thought is not confined to Pennsylvania. It has been answered variously. In one instance the reply in general stated that if the state were to do this, it would have to pay for it from taxes collected from the people offended by the pollution. Thus these people would be penalized in two ways. Many who are innocent would have to help carry the load of the guilty. Segregation of guilt would be difficult.

Others in industry have expressed the idea that everybody is responsible in some degree for pollution, therefore everybody should take part in any drive for its correction.

There are many industrial people, however, who feel that they know their own problems best. They prefer to solve these problems themselves—to have freedom either to treat the wastes or to eliminate them. All they ask is data on the extent to which treatment must be carried, and that this be put into concise, understandable terms.

Industry wants to talk of its wastes in the same way as it talks of its raw materials, its intermediates, or its products. It wants to use terms of definite concentration and condition. It wants no part of indefinite equivalents and it has talked longer and louder about this particular feature of the program than perhaps any other. And there are many in industry who feel that it should have a voice in fixing the degree of purity they must meet in their waste treatment program. This is understandable but is open to greater length of discussion than time permits here.

These matters recently have been brought to the attention of the state agencies, who reacted in a manner which could be described only as cooperative, reasonable, and logical. There is every reason to believe that before long industry and the state will join in the effort to solve specific problems. There is good reason to believe also that before long industry in the state will know, from clear and well-defined specifications, just what degree of waste treatment it must provide. It is to be hoped that the terms used will be understandable to all types of engineers and chemists in industry, for it is to these people in its ranks that industry looks for solutions for its waste treatment problems. The whole state program can be advanced or retarded depending upon what develops.

Definite Stream Standards Desired

Finally, and perhaps paramount in importance, industry is wondering how it is to know when and under what conditions it will know that the program is satisfactory or complete. Industry is accustomed to thinking of new projects in terms of demand, planning, design, construction and operation. The termination of each phase marks the beginning of the next. But each phase can be measured by a yardstick which will show its progress where visual means fail. What is the yardstick for the clean streams program?

Surely this cannot be answered in

terms or degree of waste treatment alone. Waste treatment is only a tool, like a wrench or a saw, to be used in building the recovery of a stream which has been spoiled. The recovered stream is the structure—the producing unit—for which all the effort of demand, planning, designing, construction, and operation has been expended.

Waste treatment is essential in the same manner as any tool is essential. But what will it matter if twenty or a thousand establishments discharge their waste into a stream if that stream fulfills all its values—esthetic, practical, industrial, recreational and otherwise? Will there be pressure for the spending of one dollar for waste treatment, the tool to correct something which needs no correction? It does not seem that there would be. So in the final analysis it is the stream itself in which all are interested.

Examination of the stream itself will show when the job is done. Examination of treated wastes will not serve the purpose. There are substances which may help or harm the stream for which chemical analytical methods will not suffice. The most carefully devised toxicity investigation of a waste can only establish safe levels of concentration under the conditions of the test. Such tests are extremely useful, probably more useful than the usual series of chemical tests alone, but they are not final. They will not predict the effects of interaction of treated wastes from different sources, and similar interactions which may occur in such a complexity as is a natural body of water.

But there is a way by which the success of the whole or any part of the program can be established and that is by the examination of the stream itself. The stream is an environment with parameters of condition. It is a complex, but with auto-indicators of condition and of the effects of its complexities. It readily indicates its health or disease, and even gradations of these conditions.

Industry will want to know, therefore, from disinterested umpires or from sound and proper examinations, just how well it has played the game. And the people as a whole will want to know how well all those in the game are continuing to perform—to see that streams which have recovered are being kept in clean condition.

This can be assured only by carefully planned stream surveys conducted by both aquatic biologists and water chemists. These individuals will know, each in his special way, how and where to look for the indicators of stream condition. If there is a question as to which science is the more important, it is probable that the biological phase will tell the most complete story; but for the whole story both are needed. Without such a check on the objective which both industry and municipalities are being ordered to attain, the whole program is comparable to a racetrack with a starting gate but no finish line, and everyone conceivably could go around and around and no one could say where to stop. In this case thousands and thousands of dollars could be spent going around unnecessarily.

Yet with a goal to attain, in terms of chemical and biological characteristics, which it might be said here need not be those of primeval stream purity, not only will it be known when a stream has been recovered, but there will be a recorded yardstick by which it can be known also that it is being kept clean. Industry will have something to show for the money it has spent, and can see a completed structure—a producing unit.

Conclusion

There are other thoughts which industrial people have expressed concerning the stream program. Usually, however, they are just different ver-

sions of what has been said. Time does not permit of their consideration individually. But before concluding these remarks it may be pertinent to repeat what was said some time ago when talking to another group on the subject of the Pennsylvania program, which is being watched in every section of the country. The writer has criticized the program but for no other purpose than to be constructive. He believes in the program, in its purpose, in the personnel administering it, and in its ultimate success. But it is a big program, with a new decisiveness, and no stone should be left unturned to assure that it will be made possible for all to do their share, always, however, being able to see and know clearly where and how they are going. Nothing will do more to bring industry into active participation, so that the viewpoint of industry will be, in general, a favorable one.

DISCUSSION

By F. B. Milligan

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The writer is in agreement with much of Mr. Hart's paper, especially his description of the attitude of a certain percentage of industrial management. His reference to the fact that one group considers itself persecuted by measures for the abatement of stream pollution is sober truth, incredible as such an attitude may seem. It is fairly obvious that water-using factories cannot continue to grow unless pollution is checked. It is a sufficient commentary on the quality of the citizenship of those who have been using the public streams as private sewers, free of charge, that they now have delusions of persecution because they are required to clean up. And as Mr. Hart says, this use of the public waters has been going on in some cases for the past 100 years.

This matter is mentioned with some feeling, because one of the greatest difficulties encountered in attempting to put into effect the pollution-control laws has been the delaying tactics employed by a number of industrial establishments. Such tactics are extremely hard to combat.

Many towns are guilty, too, but hardly to the same degree, since many an industry employing hundreds of people places a pollution load on the streams equivalent to the raw sewage of thousands, or tens of thousands—by any standard of comparison except bacterial. Industrial wastes very rarely carry disease germs, but domestic sewage, on the other hand, rarely carries cyanides or mineral acids, so the score there is about even.

The hard core of Mr. Hart's paper assumes the general acceptance by industry today of a pollution abatement program, for which Mr. Hart himself has worked unselfishly and long. He states that industry wants no part of "indefinite equivalents," and expects industry soon to know, by "clear and well-defined specification" just what degree of waste treatment it must provide. He has in mind requirements that are based solely on the condition of the receiving stream.

The ideal method of pollution control probably is to adjust the degree of industrial waste and sewage treatment to the use and condition of the receiving body of water, so that while a big establishment on a little stream might have to treat its wastes to a very high degree, a small plant on a big stream might have to do nothing. The writer held that opinion himself for years, and still feels that the objections to it are chiefly practical ones.

But they are overwhelming. An attempt will be made to explain them because it was these considerations which have forced him to the conclusion that requirements based solely on the condition of the receiving streams simply are not feasible.

In order to base control on the stream condition, a lot of data must be obtained and arbitrary rulings made on questions such as the following:

Where should requirements be enforced? Two feet below the plant outfall, or 200 feet, or 2 miles downstream? Should they be enforced where general admixture first occurs or at the first convenient bridge? These are practical considerations of some importance when multiplied by thousands of cases.

When should requirements be enforced? At the lowest recorded flow of a given stream or of streams in a given region? Or at drought flow defined as the average of the lowest flows continuing for 1 week and expected to occur once in 5 years? Or at ordinary low flow, the average of the lowest flows of an approximately normal year, unusual minimum flows being rejected? But note that whatever stage of the stream is decided upon, a laboriously determined rating curve (or its equivalent in observed stream conditions) must be established in order to find when the critical stage is reached, at which requirements must be met.

How should the use of the stream be allocated if several towns and industries are in the same general vicinity? The problem is easily solved if each polluter is required to render the stream as clean as he receives it, but that is a very high standard in most cases of summer trickles and large industries, and in the present state of the art of industrial waste treatment.

Then how can the assimilating power of the stream be justly allocated? On the basis of relative pollution loads? If so, on what sort of loads—solids? B.O.D.? Acids? Color? Or on the number of employees in each industry versus the number of citizens in each town, or on the ecology of the stream (ecology being defined as "biology dealing with mutual relation between organisms and their environment")?

It must be thoroughly realized that such allocation, however well worked out, would have to be reworked, with corresponding changes in treatment plant, whenever a new industry or town arose.

Therefore, despite industry's demand as voiced by Mr. Hart, "Industry is wondering how it is to know when . . . the program is . . . complete"—industry will never know that, any more than it ever will know when the automobile manufacturers will stop developing new models, or when new high-test gasolines will stop appearing.

Mr. Hart continues, " . . . What will it matter if 20 or 1,000 establishments discharge their wastes into a stream, if that stream fulfills all its values, . . . industrial, recreational and otherwise?" The necessity for each establishment's doing its share is paramount for exactly the same reasons as those which compel each citizen to pay taxes or perform military service. If 20 or 1,000 fail in their duties as citizens the country will be little affected, but if all fail the country also will fail.

It was because of considerations of this sort that the Pennsylvania Sanitary Water Board established its present requirements, which are a compromise between one extreme of arbitrary percentages of reduction for each source of pollution and the opposite extreme of requirements based only on the condition of the receiving body of water.

First, the Board took general cognizance of the use and condition of the streams of the Commonwealth on the basis of current estimates, and divided the streams into several classes with regard to the character of each stream

and the use to which it is put. The classification may be altered from time to time as knowledge increases and conditions change.

This then is an adjustment of requirements to fit the receiving stream. It is a practical step in the direction suggested by Mr. Hart.

Next, the Board set requirements for minimum percentages of reduction of the polluting characteristics of industrial wastes and sewage. This is a practical measure. It probably works some hardship, as do most regulations —however just they may be in the main —but being practical, it certainly should appeal to hardheaded business men.

In this connection should be noted Mr. Hart's statement that industry "wants no part of indefinite equivalents." In notices sent by the direction of the Pennsylvania Sanitary Water Board to industrial establishments causing pollution, the requirements for sewage treatment were stated in some detail for purposes of illustration, and it was further explained that industrial wastes must be treated to an "equivalent" degree. This phrase was used in order to permit some adjustment where circumstances indicated its fairness or necessity, pending the development of more exact knowledge respecting industrial waste disposal. It may be decided that this consideration should no longer be given to industrial polluters. The anticipated development of certain standards, however, may further simplify this matter, at least from the administrative point of view.

Finally, the Board set the requirement of additional treatment if, when, and to the degree that the stream requires it. Here, Mr. Hart and the Board seem to be in full agreement. The writer feels that improvements are desirable in the tests used to determine whether or not a particular stream requires higher treatment than the minimum. The B.O.D. test may be superseded and routine studies may include the ecology of the stream—when the time and personnel needed for such studies become available.

Even the present studies or regulations to determine the final quality of the stream are complicated, as has been shown. Such studies, however, must follow the actual construction of treatment plants, and therefore it probably will be possible to fit them into a reasonable work schedule. Meanwhile, the fish wardens will report if trouble develops, thereby proving without more ado the need for better-than-minimum treatment.

Industry has a right to ask for reasonable standards. It is hoped that they will be based on percentages of reduction of raw waste characteristics, because if that phase of the Board's policy were to be set aside, all the disinterested engineers and chemists with whom the writer has discussed the matter agree that the present stream improvement program would be delayed for years. But standards of normal raw wastes should be set up where possible, in order that an industry with good housekeeping may not be penalized with respect to a similar plant having poor housekeeping, when the Board's percentages of reduction are applied.

Mr. Hart expects that industry will soon know "from clear and well-defined specification, just what degree of waste treatment it must provide" and that "there are many in industry who feel that it should have a voice in effecting the degree of purity they must meet in their waste treatment program."

Months ago the Bureau of Engineering proposed to at least two major industries that they follow the example set by several other industries and meet with the engineers of the Bureau in order to prepare normal raw waste standards for the consideration of the

Sanitary Water Board. Thus far nothing has been done, so that it may be necessary to proceed alone.

Some concerns have wished to receive a flat permit analogous to a building permit, good once and for all, until they have come to realize that in such cases the Board would have to require treatment works far oversized to take care of the worst possible condition of wastes, overloads, low stream flows, and other contingencies—and that even then, if the establishments were to increase in size, additional capacity would have to be provided. With the "more if necessary" clause, however, the works may be designed much closer to the estimated requirements, and additions can be made later if necessary.

PENNSYLVANIA INDUSTRY FORMS SUBSIDIARY COMPANY TO DISPOSE OF WASTES

In compliance with the Pennsylvania Clean Streams Program, the Wheatland Tube Co., of Wheatland, Pa., has organized the Maneely Chemical Co. as an affiliate unit to manufacture byproducts from wastes that are now discharged to streams. The Wheatland Tube Co. is a large producer of steel pipe and tubing for industrial and residential uses.

Construction of the byproducts plant on a site adjacent to the parent company's plant property was begun in January, 1948. The Maneely Chemical Co. will employ recently developed processes for the recovery of zinc sulfate, zinc chloride, zinc ammonium chloride, and pigment grade iron oxide from the Wheatland plant wastes. Production of these materials is scheduled for the latter part of 1948.

INDUSTRIAL WASTE DISPOSAL INSTRUCTION COURSE

An instruction course on industrial waste disposal and stream pollution control for sewage and industrial waste treatment works personnel was inaugurated February 20, 1948, at Detroit, Michigan. The course is sponsored by the Committees on Education of the Michigan Sewage Works Association and the Michigan Section of the AWWA, with the University of Michigan Extension Service cooperating.

Subject matter for the course is designed to present the fundamental aspects of the disposal of liquid industrial wastes and the effects of such wastes on receiving streams and sewage treatment works. Instruction will be directed by several recognized authorities of the waste treatment field.

Instruction classes are being held one night each week for twelve weeks. Mr. J. E. Cooper, Ford Motor Company, is the course leader.

LIQUID-PHASE AND FOAM-PHASE OXIDATION OF WASTE SULFITE LIQUOR*

By Robert P. Logan and H. Heukelekian

Assistant and Associate Research Specialists, respectively, Rutgers University, New Brunswick, N. J.

Of the many wastes produced by the paper industry, waste sulfite liquor is generally accepted as being a major problem from the standpoint of both stream pollution and difficulty of treatment.

The importance of the problem is attested by the numerous investigators who have given attention to it. The biological treatment processes that have been described include activated sludge (1, 2), trickling filters (3, 4), and the yeast production processes. The latter are byproduct recovery methods which effect a considerable degree of treatment.

In the course of studies in the writers' laboratory, two general methods of treatment of sulfite liquor were developed, both based upon aeration. The first method—direct aeration—was applied where the rate of air application was just high enough to prevent extensive foaming. This method was called "liquid-phase oxidation." The second method of direct aeration was used to convert the liquid completely to foam, and was called "foam-phase oxidation." In the first method, the biological organisms used (seed) were in the form of a dispersed, nonflocculent growth, whereas, in the foam-phase treatment, an attached growth was developed.

Previously used biological methods, such as activated sludge and trickling filters, required dilution of the strong sulfite waste in order to obtain reasonable degrees of stabilization. In the methods described in this paper, the treatment of full strength waste was one of the goals.

The authors believe that foam-phase treatment represents a new approach to the problem of carrying on biological oxidation of wastes.

Waste Liquor

The waste liquor used in the experimental work was Clarion Extract obtained from the Costania Paper Company. It had been concentrated to 49.3 per cent solids, and had a sulfur dioxide content of 1,700 p.p.m. The loss of sulfur dioxide content during evaporation makes the waste noncomparable to normal sulfite waste liquor and possibly affects the results favorably.

The dilution of the concentrated waste used most commonly was 1 to 5, which gave a 5-day B.O.D. of 19,000 p.p.m., which corresponds to the actual strength of the wastes discharged from a mill. Sufficient nutrients, in the form of ammonium chloride and dipotassium phosphate, were added to supply the needs of the microorganisms. Minimum nutrient requirements were not studied during this part of the work.

Analytical Procedure

In general, analytical procedures were in accordance with "Standard Methods." However, dissolved oxygen was measured with the sodium azide modification of the Winkler method, and alkaline sodium iodide with a short period of alkalization. No

* Journal Series Paper of the New Jersey Agricultural Experiment Station, Dept. of Sanitation, Rutgers University, New Brunswick, New Jersey.

appreciable differences were noted between this and the alkaline hypochlorite modification. Formula C dilution water was used for all B.O.D. determinations.

Liquid-Phase Aeration

The use of dispersed cells for this treatment, instead of flocculent growths, was based on the results obtained from work with other types of wastes. The aeration of such concentrated waste normally does not produce flocculent growths, but instead the microorganisms tend to grow dispersed in the medium. As a result, the removal of B.O.D. is by actual oxidation rather than by transference of a part of the organic impurities into the floc. Consequently, no sludge is formed and the recovery of fertilizer material is not feasible.

Development of Culture

The original inoculum was obtained from lawn soil. The method consisted of adding the soil suspension to the diluted and enriched waste liquor and aerating it. By successive transfer, a natural enrichment took place and microorganisms adapted to the waste became established. Yeasts and bacteria were found in the seed, but no protozoa or fungi.

Diffused Air Aeration with Mixed Cultures

With the acclimatized culture obtained, the treatment of the sulfite liquor was started on a batch basis employing a 24-hour aeration period. Liquor aerated the previous day was retained as seed in the amount of 25 per cent by volume. Aeration was accomplished by passing compressed air through diffuser tubes.

The quantity of air input was limited by the extensive foaming, so that only enough air was used to prevent the foam from going over the top of the conical vessel employed. At intervals the B.O.D. of the aerated liquor was determined. During a period of three weeks, B.O.D. reductions never exceeded 32 per cent and at times were as low as 10 per cent, with an average reduction of 22.6 per cent.

Although the original intent of the work was to develop a method for the treatment of undiluted sulfite liquor, the rather poor results obtained with the undiluted material prompted, in some instances, a study of waste diluted to 7,300 p.p.m. of B.O.D. Dilution of the waste would decrease the oxygen demand, and the supply of air, limited by foaming, would become adequate.

Operation on a fill-and-draw basis, using a 24-hour aeration period and retention of 25 per cent seed, continued for one month, showed only a slight improvement over the treatment of the undiluted waste. The average removal of B.O.D. was 26.7 per cent. Daily variations were considerable, ranging from 3 to 41 per cent B.O.D. reduction.

Studies pertaining to the effect of pH showed that the percentages of B.O.D. reduction were not affected materially between pH 4 and 7.

Treatment with Pure Oxygen and Mixed Cultures

In order to eliminate the possibility that a deficiency in oxygen supply was responsible for the low B.O.D. reductions, the waste sulfite liquor was shaken mechanically and intermittently with oxygen in a closed system, which at the same time permitted measurement of the rate of oxygen utilization.

The aeration period was 24 hours, and 20 per cent by volume of the treated liquor was retained as seed. The average B.O.D. reduction over a 16-day period was 32.1 per cent, varying from about 25 per cent to about 45 per cent.

The low B.O.D. reductions were apparently not caused by a deficiency of

oxygen. Measurements showed that the maximum rate of oxygen utilization was about 150 mg. per liter per hour, whereas the minimum oxygen supply was about 210 mg. per liter per hour. Since at all times an excess of oxygen existed, the low B.O.D. reduction was probably due to the inadequacy of the seed material. The seed may be inadequate if the number of organisms is low or if the proper type organisms are not used.

To increase the number of organisms without increasing the volume of seed, a heavy slime growth from foam-phase treatment was used. The growth was thoroughly dispersed and used in the ratio of 1 to 2.6 parts of waste sulfite liquor, both on dry solids basis.

Sulfite liquor samples of 19,000 and 9,500 p.p.m. B.O.D. were used, and the seeded liquor was shaken with oxygen. The stronger waste showed an average B.O.D. reduction of 32 per cent, while the more dilute waste gave a B.O.D. reduction of 34 per cent. It appears that even with an abundant supply of oxygen and with a heavy seeding it was not possible to obtain much better than 30 to 35 per cent B.O.D. reduction by the application of air or oxygen to the liquid waste.

Treatment with Pure Oxygen and Pure Yeast Cultures in Dispersed State

Cultures of *Torula utilis* and bakers yeast were propagated on diluted and enriched waste. The treatment was with oxygen in a closed system, described previously, for a period of 24 hours, 17 per cent by volume of the liquor being retained each day as seed. The average B.O.D. reductions were 30.5 per cent for the *Torula* and 23.6 per cent for the bakers yeast. With *Torula* the maximum reduction was 43 per cent.

Foam-Phase Treatment

The previously described experimental work indicated no promise of great success in the treatment of undiluted waste sulfite liquor by liquid-phase aeration. The amount of oxygen that can be supplied to undiluted waste sulfite liquor by air is limited by the tendency of the waste to foam. Even when pure oxygen was used the results were unsatisfactory.

Since the foaming of the waste could not be prevented during aeration, treatment of the waste in the foam state suggested itself. Such a process, if feasible, would have the advantage of a greater supply of oxygen at the liquid-air interface.

Oxygen dissolves in a liquid at the gas-liquid interface. A narrow region around the bubble quickly becomes saturated with the gas and further solution is limited by the rate of the gas diffusion away from the saturated zone.

Ordinary aeration processes are inefficient, but with dilute wastes, aeration does not become a limiting factor. With concentrated wastes, such as sulfite liquor, aeration may be a limiting factor: first, because the biochemical utilization of oxygen is high; and second, because the high concentration of dissolved matter limits the solubility of the oxygen.

To increase the efficiency of aeration it is necessary to increase the air-liquid interface. It would appear that liquid in a completely foamed condition would represent the ultimate in air-liquid interfacial area.

To approach maximum air-liquid contact, waste sulfite liquor was completely converted to foam in 4-ft. long glass tubes mounted vertically, each equipped with an air diffuser plate at the bottom and a large funnel mounted at the top to provide holding space for excess foam to allow for foam breakage.

In all foam experiments the waste was fortified with nutrients in the form of ammonium and phosphate salts. The microbial culture was developed as described previously.

In the first experiment, waste containing 20 per cent developed seed was

foamed for three days with the following results:

Days Aeration	5-Day B.O.D. (p.p.m.)	Per Cent Reduction
0	19,700	0
1	11,970	39.4
2	6,750	65.8
3	4,590	76.7

Even the first day's result indicated a distinct advantage over liquid-phase aeration. The foamer was then operated with a daily addition of two-thirds of the capacity, one-third of the treated liquor being retained daily as seed. After two weeks of such operation a tan biological slime developed on the walls of the foamer.

With operation on a daily feeding schedule, after the attached growth had been established, analyses indicated the following results:

	Treatment Period (hours)	B.O.D. (p.p.m.)	Per Cent Reduction
Feed Liquor	—	19,950	—
Treated Liquor	24	4,230	78.8
Treated Liquor	24	3,820	80.9
Treated Liquor	24	3,440	82.8
Treated Liquor	48	3,240	83.8
Treated Liquor	24	3,000	85.0
Treated Liquor	24	2,270	87.7
Average of 24-hour results			83.0

The remarkable improvement in B.O.D. reduction was attributed to the development of the attached biological slime which had developed in the foamer.

To prove that the attached growth was the effective agency, another foamer without the attached growth was operated concurrently with the one described above.

The tube without the attached growth as well as the one with the initial attached growth was seeded with the treated liquid in the ratio of 1 volume of seed to 2 volumes of raw waste. Some results expressed in percentage of B.O.D. reduction were as follows:

Day	Attached Growth	No Attached Growth
1	85.0	58.0
2	87.7	74.5
3	—	73.7

The rapidly increasing efficiency of the new foamer was accompanied by a quick development of growth attached to the foamer walls. It was concluded that liquid seed was not necessary, and in the remaining work none was used.

When the foamer was operated with only attached growth, it was entirely drained of the treated liquor and charged with fresh liquor. Thus no liquid seed was present other than that which clung to the biological growth on the container walls.

The average results obtained with attached growth only showed that a B.O.D. reduction of 80.3 per cent was obtained in 24 hours. Figure 1 shows the results from experiments with attached growth only, in which the air was metered. Six hours of foaming gave a B.O.D. reduction of 50 per cent with a consumption of 125 cu. ft. of air per gal. of liquid. The 24-hour reduction was 87 per cent.

Although the air consumption appears very high, examination of the curve during the first 4 hours, when the B.O.D. curve is approximately straight, shows that the reduction amounts to 0.65 lb. B.O.D. per 1,000 cu. ft. of air applied. Increased efficiencies of air usage would probably result if taller foaming columns were used.

Continuous Foam-Phase Treatment

To determine whether or not continuous treatment by foam-phase oxidation was practicable, a laboratory scale apparatus was used consisting of a 4-ft. long, 2½-in. diameter tube equipped with a diffuser and overflow funnel. To provide continuous feed, a small chemical feed pump controlled

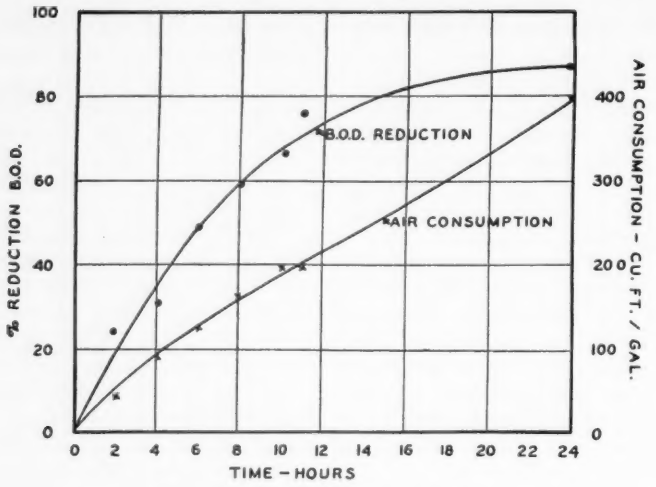

FIGURE 1.—Rate curve (24-hr.)

by a time clock fed the raw sulfite liquor to the top of the foaming chamber. An overflow siphon allowed an equal amount of treated waste to escape from the bottom of the chamber. The detention time was varied by changing the pumping period. Ordinarily, 2 or 3 pumping periods per hour were used.

In the first series of tests, a heavy growth, which had been developed over a period of several weeks, was used. The results were not as satisfactory as with batch treatment, especially during the first 8 hours.

During the course of these experiments, the rate of film buildup was very rapid. The growth became so thick that a major portion appeared to be anaerobic.

To determine whether the age and thickness of the growth were signifi-

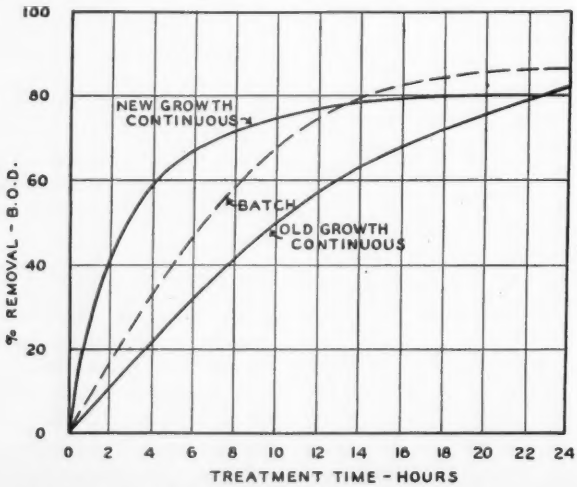

FIGURE 2.—Comparison of batch and continuous treatment, foam-phase oxidation.

cant, another series of continuous treatment runs were made using a relatively new and thin growth.

The results of both series are compared with the average results from a series of batch treatments in Figure 2. Both old and new growth gave approximately the same reduction in 24 hours and this reduction was only slightly less than that attained with batch treatment. However, during the first 12 hours the new growth gave much better results than batch treatment, while the old growth gave poorer results. It appears that a thick growth is not necessary and may, in fact, be less desirable.

Foam-Phase Treatment with Pure Yeast Cultures

To determine the action of yeasts in foam-phase treatment and to compare foam-phase with liquid-phase aeration, experiments with pure cultures of baker's yeast and *Torula utilis* were utilized and further developed by foaming. After each period of foaming, the treated waste was centrifuged to remove the yeast cells, which were then re-inoculated into a fresh batch of waste. Some typical results were as follows:

Treatment Time	Culture	B.O.D. Reduction (%)
24 hours	Baker's yeast	53.5
24 hours	*Torula utilis*	64.6
46 hours	Baker's yeast	63.0
46 hours	*Torula utilis*	61.5

It is apparent that about 65 per cent of the B.O.D. was amenable to treatment with yeasts. *Torula utilis* appeared to be more active than the baker's yeast. Foam-phase treatment with yeasts yielded better results than liquid aeration with yeasts, but not as good as mixed-culture, foam-phase treatment.

The behavior of yeasts under the conditions of foam-phase treatment is interesting. Attached growth occurred with a relatively heavy film, which sloughed off easily. No anaerobic conditions resulted within the film.

Nature and Behavior of Biological Slime from Mixed Cultures

During the first period, when laboratory foaming units were used, the time of film development varied from several days to 2 weeks. As the attached growth developed, the turbidity of the treated liquor decreased, indicating an increase in predominance of attached growth over the dispersed growth.

It was found that with laboratory units the growth was liable to sudden and complete sloughing after 40 to 50 days of development. The growth was black on the side toward the walls and appeared to be anaerobic in this region. The foam, or aerobic side, was tan colored and had a rough, pebbled surface. The film thickness may exceed 1/8 inch. One striking feature of the growth was its tough and rubberlike nature. Pieces of the material up to 3 ft. long were picked up without tearing. Figure 3 shows a sample of the film.

Microscopic examination of the growth revealed a matlike growth of fungi; bacteria and yeasts of both the budding and rod type were present, but protozoa were absent.

An analysis of the unwashed slime film scraped from the walls of the foamer showed it to contain:

Solids	23.8 per cent
Volatile Matter	72.5 per cent
Total Nitrogen	2.81 per cent
P_2O_5*	0.86 per cent

* On dry solids basis.

It was estimated that 15 to 20 per cent of the solids in the waste sulfite liquor were recovered as slime.

Although all experiments were conducted with the growth attached to the glass walls of the foamer, tests showed that the growth would grow equally well on woodchips, paper, cork, and many other materials.

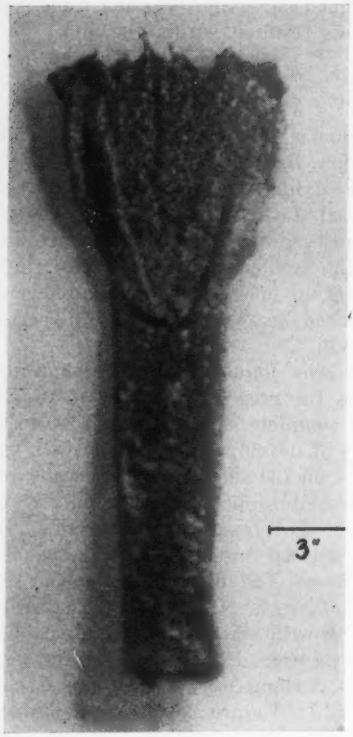

FIGURE 3.—Sample of biological slime developed in foam-phase aeration studies.

Mechanics of Foam Production

Since the degree of expansion of foam might be a determining factor in the practicability of the foam-phase process, studies were made to determine what degrees of expansion might be encountered. The use of glass diffuser plates of varying porosities and various rates of air transmission revealed that expansion ratios of volume of foam to volume of liquid converted to foam could be kept under 10, if the permeability of the diffuser plate was less than 36. The rate of air passage appeared to be of secondary importance.

Control of the degree of expansion of the foam is desirable for several reasons. Obviously, some control is required to contain the foam within the equipment. It appears that there exists some optimum bubble size, which will effect most efficient transference of oxygen to the liquid. If the bubble is too small, too little air is associated with a given volume of liquid, and if the bubble is too large, the reverse is true.

In general, ideal foaming occurs when the rate of flow of air, the diffuser type and area, and the nature of the waste are such that the rate of foam formation at the diffuser surface is just matched by the rate of liquor return from the broken foam. Under these conditions the formation of large bubbles is avoided and expansion kept at a minimum.

Satisfactory foamer operation was also obtained with a venturi pick-up for the air. The waste was pumped through the venturi in which it was mixed with air and emerged as a foam.

Discussion

The factors to be considered in aerobic treatment of waste sulfite liquor are: (1) maintenance of aerobic conditions, (2) nature and concentration of the cultures.

The maintenance of aerobic conditions depends upon the rate of aeration and the dilution of the waste. When compressed air is used for aeration purposes, a foam is produced; therefore, the maintenance of a liquid phase and aerobic condition is impossible. Although no actual dissolved oxygen determinations could be made, it is possible that dissolved oxygen became a limiting factor in the aeration of the liquid with dispersed cells. It was necessary to reduce the rate of aeration in order to prevent the conversion of the liquid to foam. With dispersed cells, normal air diffusion and a full strength of waste, a maximum B.O.D. reduction of about 30 per cent was obtained in 24 hours, and an average reduction of 22.6 per cent.

When aerobic conditions were assured by shaking the liquor in the

presence of pure oxygen and dispersed mixed cultures, the B.O.D. reductions were only slightly higher, averaging 32 per cent.

Three types of inocula were used in the studies with dispersed cells, namely: (a) original culture developed from soil, (b) dispersed slime growth from foam-phase treatment, and (c) yeast cells. None of these cultures in dispersed state reached a high degree of efficiency in the presence of an ample oxygen supply.

The treatment with dispersed cells seems to be unsuitable for the treatment of such strong wastes because of the difficulty of maintaining dissolved oxygen with normal air and because of the lack of concentration of organisms capable of consuming the concentrated food materials.

Foam-phase treatment, however, proved successful for the treatment of sulfite liquor with either mixed cultures of organisms or with pure yeast. Reductions of 80 to 85 per cent B.O.D. were obtained with mixed cultures in 24 hours and 50 per cent reductions were obtained consistently in 6 hours. Yeast cultures did not prove as efficient as the mixed cultures, since only 65 per cent reduction was obtained with *Torula* and 55 per cent with baker's yeast.

A comparison of results obtained by liquid-phase and foam-phase oxidation is shown graphically in Figure 4, where average results are plotted. It is evident that a mixed-culture, foam-phase treatment is nearly 4 times as effective as liquid-phase treatment, and that *Torula utilis* foam phase and air is over twice as effective as liquid-phase aeration with pure oxygen.

With a naturally stable foam-forming waste, such as sulfite liquor, the foam-phase treatment seems to be ideally suited because the favorable conditions required for the successful treatment of a concentrated waste prevail. A large mass of diversified organisms attach themselves to the surface. The organisms are bathed continuously with a thin film of liquid containing food, and the oxygen is supplied to the active surface. The aeration is similar to that taking place in the trickling filter; the difference consists in the method of bringing the material in contact with the active surfaces.

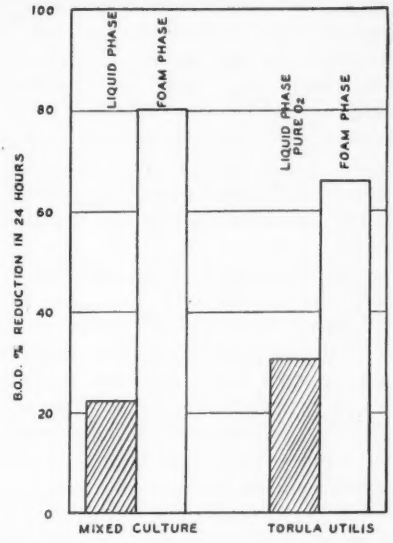

FIGURE 4.—Effectiveness of foam-phase and liquid-phase aeration.

It is difficult to project and predict from laboratory scale experiments the performance and difficulties of a large scale installation. High efficiencies, both from the standpoint of B.O.D. reduction and air utilization were obtained. If the basic principles can be incorporated in the design of a large scale plant, there seems to be no reason why at least equal performance results cannot be obtained.

The question of thickness of film and of the method of loosening and discharging it remains to be solved. If the film in a large installation should discharge suddenly after reaching a certain thickness, the efficiency would drop for a time.

The growth could be relatively easily recovered for fertilizer purposes, as it settles readily and has a moisture content lower than that of activated sludge cake from a vacuum filter. However, the nitrogen content is materially lower than that of activated sludge and is more nearly comparable to the nitrogen content of digested sludge.

Some experiments indicated that it should be possible in a large scale installation to grow the organisms on an inert surface such as sawdust or waste bark, wasting an appropriate amount of this growth-carrying, inert medium daily. By this method the sludge problem would be more uniform and the growth could be kept young and active. Results have shown the young growth to be more effective than old growth during the first half of a one-day foaming period.

The results with yeasts are significant in view of the interest shown by the industry in the production of fodder yeast from waste sulfite liquor. If the attachment of yeasts to fixed surfaces noted in these experiments can be promoted, the problem of recovery of the yeasts from the liquor will be considerably lessened.

Summary and Conclusions

Laboratory experimentations with concentrated waste sulfite liquor resulted in the development of an improved method of bringing the waste in contact with biological growth and the maintenance of a constant supply of oxygen in close proximity to the food and organisms.

Two types of treatment were studied. One, in which oxygen was supplied to the liquid waste, either as air or as pure oxygen, was termed "liquid-phase treatment." The other, in which the supply of air used converted the sulfite liquor entirely to foam and in which attached growth developed, was termed "foam-phase treatment."

The following conclusions were drawn from the results of the work:

1. The treatment of diluted or concentrated sulfite liquor with compressed air and dispersed cells produces a stable foam, limits the quantity of oxygen supply necessary for oxidation, and gives a B.O.D. reduction not in excess of 30 per cent in one day.

2. Shaking of the sulfite liquor in the presence of pure oxygen with a mixed culture of dispersed cells gives a B.O.D. reduction not in excess of 35 per cent in one day.

3. Shaking of the sulfite liquor in the presence of pure oxygen with pure cultures of *Torula utilis* and baker's yeast in dispersed cells did not increase the efficiency obtained with mixed cultures under otherwise similar conditions. *Torula* gave somewhat higher reductions than baker's yeast.

4. Foam-phase treatment with attached cultures gave 80 to 85 per cent reduction in 24 hours, and nearly 50 per cent in 6 hours.

5. Foam-phase treatment employing *Torula utilis* and baker's yeast gave reductions of 60 and 50 per cent, respectively, in 24 hours. Attached growth occurred.

6. Continuous foam-phase treatment gave 24-hour results similar to those of the batch process. When new growth was employed, the continuous treatment gave markedly better results in the first 12 hours.

Acknowledgment

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INTER-AMERICAN SANITARY ENGINEERING CONGRESS SCHEDULED

The Chilean Section of the Inter-American Association of Sanitary Engineering (IAASE) has now announced definite plans for the First Inter-American Sanitary Engineering Congress. The Congress will be held at the University of Chile, Santiago, Chile, on April 8–14. Sponsoring agencies include the Chilean Section (IAASE), the Ministry of Public Works of Chile, the Ministry of Public Health of Chile, the Department of Water and Sewerage of Santiago, the Pan-American Sanitary Bureau, and the Institute of Inter-American Affairs.

This Congress will follow the pattern of the two preceding regional meetings held in Rio de Janeiro, Brazil, and Caracas, Venezuela, in 1946, and there will be in attendance not only sanitary engineers, but also public health and public works officials and allied professionals from all the American Republics.

A balanced program designed to appeal to the sanitary engineer, whether he is in the field of public health, public works, private consulting work, or manufacturing has been planned. Among the outstanding items of interest are inspection trips to the Las Vizcaches water treatment plant and the Villa Alemana sewage treatment plant near the famous ocean resort of Viña del Mar.

One of the most important matters to be placed on the Congress' agenda is the establishment of the Inter-American Association of Sanitary Engineering on a permanent basis. During the past year, the Association has functioned in an interim status through a temporary Advisory Committee and an Acting Secretary.

A large exhibit of water-works and sanitation equipment will be staged in the exhibit hall adjacent to the University of Chile auditorium and will be an important adjunct to the meeting. Manufacturers from all the American Republics have been invited to exhibit.

For further information on the Congress, inquiries may be addressed to the conference chairman, Mr. Ruperto Casanueva, Departamento Cooperativo Interamericano de Obras Sanitarias, Tenderini 127, Santiago, Chile, or to the Inter-American Association of Sanitary Engineering, c/o Donald L. Snow, Acting Secretary, 2001 Connecticut Avenue, N. W., Washington 8, D. C.

Stream Pollution

BIOLOGICAL ASPECTS OF STREAM POLLUTION *

By A. F. Bartsch

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The entry of pollutants into a flowing stream sets off a progressive series of physical, chemical and biological events in the downstream waters. Their nature is governed by the character and quantity of the polluting substance. Domestic or industrial effluents may adversely affect natural stream life by direct toxic action or indirectly through quantitative alterations in the character of the water or the stream bed. These facts imply that the presence of polluting substances produces physical, chemical and biological changes that may be recognized as dependable criteria of stream conditions.

The value of physical and chemical data is recognized generally by those concerned with stream pollution and its control. Methods used in gathering these data are fairly well standardized and practiced. Biological procedures have not, as yet, attained an equal degree of refinement. In some ways this is surprising, for the complex interactions resulting from stream pollution are predominantly biological. The determinations of biochemical oxygen demand and dissolved oxygen are essentially for the purpose of finding out how much bacterial food is available and how the bacteria like their diet. Other applications of these data are well known.

The biological phase of stream sanitation is still an infant science, with many of its procedures, refinements and applications still to be worked out. For this reason the following discussion is of a general nature and refers primarily to stream pollution resulting from the introduction of raw or partly treated sewage. Industrial or toxic types of wastes are not considered. Personal field observations and the publications of others have been drawn upon freely for interpretation.

Biological aspects of stream pollution will be considered in a general way from two separate but related points of view: (1) how pollutants change the character of the stream as a habitat for organisms, and (2) the action of organisms upon the pollutant and their related distribution.

The fundamentals of stream biology may best be illustrated by reference to a fictional stream whose hypothetical character may be molded with a free hand. This stream has a semi-solid bottom, medium gradient, average width of about 75 feet, and depth of 6 feet. It flows through alternating wooded and cultivated areas. It is blessed, for our purpose, by having a single source of man-made pollution—the community of Windmill. Sewage is discharged directly to the stream.

The stream water reaching this community is not pure, for the word, as commonly used, is only relative. Drainage from the land already has added humus extracts, organic particulate matter and inorganic salts leached from the soil. Drainage from cultivated land is rich in the elements that stimulate plant growth, and pasture lands contribute organic wastes

* Presented at Twentieth Annual Convention, Central States Sewage Works Assn.; Duluth, Minn.; June 20, 1947.

and intestinal bacteria. These contributions are sometimes called "natural pollution." Whether the origin is natural or from a sewer outlet, the stimulatory effect upon organisms is the same in principle. The recognizable result is that the unpolluted stream supports a variety of organisms as a normal biota.

Effects of Pollution on Biological Environment

The entry of pollutants changes in many ways the conditions under which stream organisms normally live. This discussion can consider only a few, but there are changes in the stream bottom, in the physical and chemical properties of the water and in the competitive relations of organisms.

Sewage is a complex mixture of many kinds of substances that have been discarded by man because, to him, they have no further value. The constituents are organic and inorganic, simple compounds and complex ones. The organic substances include carbohydrates, proteins and fats as well as their decomposition products. There are salts of various kinds including ammonium salts, nitrates and nitrites. Organic growth stimulators also are a part. Some of the sewage substances are in solution, some colloidal and others suspended but capable of settling. It follows, then, that a recipient stream will have its waters affected by all fractions of the sewage while the stream bed is altered primarily by settling particulate matter.

If the stream is represented graphically (Figure 1) with mileage distances (or hours of flow) on the horizontal axis, the fictional community of Windmill is located at the zero level. Distances upstream are to the left and downstream to the right. The intensity of varying environmental conditions is plotted along the vertical axis. Food for organisms—chemists call this B.O.D.—is shown as curve F. The introduction of sewage tremendously augments the normal supply and thus alters this environmental factor. As the food supply is increased by pollution, the bacterial population tends to increase in geometric proportion and draws upon the available food (Figure 4). It is to be expected that the food supply will decline downstream and will eventually approach the pre-pollutional value. This is found to be a fact.

All organisms require oxygen for the maintenance of life. When applied to food, it functions in releasing the life-supporting energy that foods contain. Man draws upon the atmospheric sup-

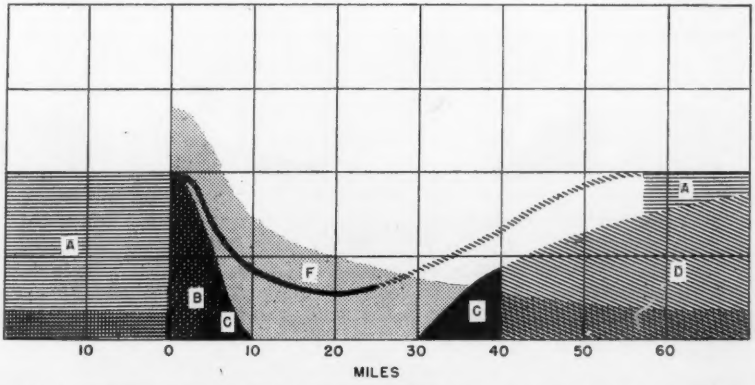

FIGURE 1.—Graphic representation of hypothetical polluted stream showing relationship of biotic food supply (F) and dissolved oxygen sag curve.

ply by breathing, while most aquatic organisms draw upon the oxygen dissolved in water. Bacterial reduction of the pollutional food supply—desirable and necessary as it may be—is not accomplished without cost. That cost is reduction in dissolved oxygen concentration beyond the point required by desirable water animals.

The normal oxygen value of clean water is shown as areas A, from this level to 40 per cent of saturation as B, lesser concentrations as C, and those increasing beyond 40 per cent of saturation as D. These areas also mark the arbitrary limits of stream zones based upon oxygen concentration. The descriptive names are *clean water* for *A*, *degradation* for *B*, *active decomposition* for *C* and *recovery* for *D*.

If the pollutional load is fairly light or the dilution factor high, the sag curve resembles the upper curved line with normal value reestablished at 58 miles. This is accomplished by addition of oxygen from the atmosphere and through the activity of green plants. Where the content of organic matter is sufficiently high, dissolved oxygen may be reduced to zero through the oxygen-absorbing efficiency of bacteria. This is the ultimate in organic stream pollution and the circumstance upon which the following discussion is based. This poorest of stream conditions will be discussed since conditions that are less severe are then readily apparent also.

Ten miles below Windmill is the beginning of a 20-mile zone in which dissolved oxygen is absent entirely. Here, the biotic demand for oxygen is greater than the supply provided by solution from the atmosphere. Bacteria and certain other organisms occupying this septic region are obliged to obtain the required oxygen from other sources. This they do by reducing oxygen-bearing compounds by anaerobic processes. Such activity may result in depleting the supply of oxygen found chemically in nitrates and nitrites, and reduces sulfates to hydrogen sulfide with its offensive odor and toxic action. These are some of the causes for rising gas bubbles and sludge in the septic zone. The gases alone make living conditions here unattractive for most forms of life.

Stream environment is further affected by the suspended semi-solids of sewage (Figure 2-A). These affect green free-floating stream life by immediately decreasing the transparency of the water and blotting out the sunlight. Downstream from the sewer outlet the water is turbid and slightly brownish, becoming dark and murky

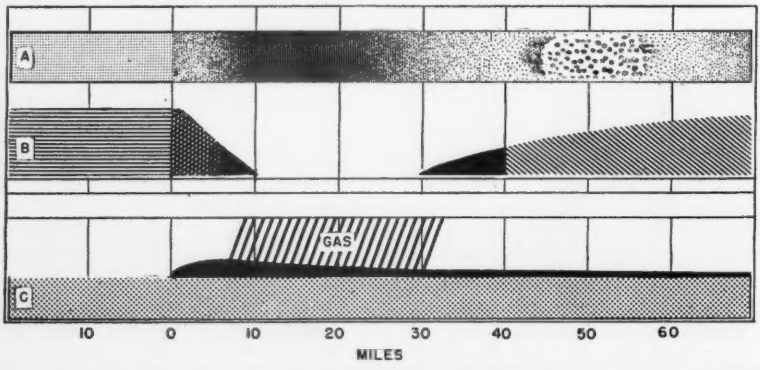

FIGURE 2.—Biotic habitat alterations resulting from stream pollution. (A) Physical changes in water resulting from entry of raw sewage at zero mileage level; (B) dissolved oxygen sag curve; and (C) accumulation of bottom sludge deposits and rising gas bubbles.

in the septic zone. As oxygen is added downstream by reaeration, the water gradually clears and finally is tinged with green by suspended microscopic plants.

Organisms that live in the stream bed are also affected by the suspended matters of sewage. These finally settle to the bottom (Figure 2-C) as a blanket of debris that effectively covers the normal habitat of clean water bottom life. It is an inexhaustible source of food but will sustain only those organisms that can qualify for life in that habitat. They must be efficient in obtaining oxygen, for conditions frequently are anaerobic. They must be able to burrow and creep so as to stay on top of the steadily growing layer, or else must be indifferent to being covered over. They must resist the toxic action of hydrogen sulfide and other gases that may emanate continuously from the deeper sludge layers.

Thus, it is seen that sewage alters the normal conditions of food supply, dissolved oxygen, turbidity, bottom surface, and chemical character of the stream and its bed. These are but a few of the environmental alterations that result from sewage pollution. They are sufficient to show that biological changes are sure to follow. Alteration in the competitive relations of stream life will be shown in subsequent discussion.

Action of Organisms Upon the Pollutant and Their Related Distribution

It is apparent that most modern methods for the treatment of sewage depend, at some stage or another, upon the activities of living organisms. So much is this the case that all sorts of schemes have been devised for pampering the biotic associations and fostering their work. Biological competition is removed in the wastage of activated sludge, and oxygen is supplied to excess. The trickling filter brings the organisms food and oxygen and washes away their metabolic wastes and products. In the sludge digester, they are kept warm so their work proceeds properly and at a rapid pace. In the final analysis, the modern treatment plant is an artificial, telescoped, polluted stream with the zone of degradation at the primary tank and the recovery zone in the final effluent. The high efficiencies obtained are related entirely to these artificial stimulatory conditions, for the fundamental biological processes are the same as in the less efficient stream.

It has been shown that sewage is food, stimulation and habitat for simple forms of life, and that reduction in the organic stream load is accompanied by a corresponding extraction of oxygen. It is not the intent of this discussion, nor within the ability of the writer, to give in detail the precise bacterial activities involved in this accomplishment. At the same time, the basic information is important and needs consideration.

The millions of bacteria in sewage-laden waters are of a variety of kinds and have a variety of abilities. Some of these are normal inhabitants of both clean and foul water. The presence of sewage stimulates their population increase (Figure 4). Others find their way into the stream in tremendous numbers as normal inhabitants of sewage. Some bacteria are able to multiply in the stream, while others such as *B. coli* and disease producers appear to die off gradually downstream. They may starve to death, be eaten by predators, be killed by high acidity, or disappear in still other unknown ways. In any event, the population peak is in the near downstream vicinity of the pollutional source.

Some bacteria can act upon a given organic compound, derive energy and growth material from it, and leave an altered residue that serves a different bacterial species or other organism in the same manner. In this way, chains of progressive actions are set in motion

that result eventually in the transformation of sewage to simpler, innocuous substances. Some of these are carbon-dioxide and water from carbohydrates and fats, and salts of phosphorus, sulfur and nitrogen from protein. Evidence of this mineralizing process is found in the progressive quantity shift from organic nitrogen, to ammonia, to nitrites and finally to nitrates as the water proceeds downstream.

As bacteria grow and multiply, selected constituents of the sewage are incorporated into their living substance. The ability to do this distinguishes all nonliving from living matter. It is an important ability, for in its practice a part of the sewage is set aside momentarily for action at a later time. On this account, bacteria sometimes are called concentrators of the pollutional load.

These activities of bacteria proceed in all parts of the stream. They are distributed throughout the water and are mixed into and over the bottom deposits. Under conditions of intense pollution, dissolved oxygen eventually is depleted in the flowing stream. Such depletion is more frequent and widespread in the bottom sludge. When this condition prevails, as from the 10 to 30-mile levels in the illustrative stream, bacterial action becomes of a different sort. In this septic region bacteria that are able to do so, act upon oxygen-bearing compounds in such a manner that oxygen from outside sources is not required. These bacteria are commonly called anaerobes. Their actions are to be prevented, if possible, for their products are various acids and such gases as ammonia, methane and hydrogen sulfide. Living conditions here are suitable only for organisms unaffected by these products and indifferent to oxygen supply.

Biological action in the stream continually decreases the food supply so that at 50 to 60 miles the concentration approximates the upstream values. Bacteria decrease in much the same pattern so that normal populations are attained at about the same level.

In addition to bacteria, unpolluted streams support a variety of other kinds of organisms. Those forms that produce their required food from minerals, carbon dioxide and water are members of the plant kingdom. Animals are those that require a supply of food already prepared. Bacteria and molds resemble animals in their food habits, but are classed as plants that lack the ability to make food. Organisms may be classified further by their position in the stream. Those that are small, suspended in the water and swept along with the current, are called the plankton. Plankters may be either plant or animal. Organisms that are attached to, lie upon, creep over or burrow into the stream bed are called the benthos. As has been stated, the bacteria occupy all of these positions. Large animals such as fish, frogs and turtles are not considered in this classification scheme.

Clean waters support a wide variety of organisms consisting of plant and animal plankton as well as benthic organisms. They are exacting in their habitat requirements and are affected by any interfering alterations. Normal changes in temperature, light, dissolved oxygen and food supply tend to result in shifts in the population picture. These, however, are rarely great, for predation, death and growth moderate the changing tendency and keep the biotic society in balance. In this society are organisms ordinarily associated with clean stream conditions. Some of these are game fishes such as trout, bass, blue-gills and pike, and smaller animals such as mussels, crayfish, snails and the larvae of caddisflys, stoneflies and dragon and damselflies. Shrimplike scuds may be present, swimming about on their sides or climbing over vegetation. A complete list of these organisms would be a long one.

In such a list of inhabitants would be the names of some organisms that are just holding their own, never building an appreciable population. Competition is too keen, food supply too low, and the habitat not quite suitable. Some of these would fare better in the polluted portions of the stream.

Significance of Biological Population

The remainder of this discussion is based upon the principle that organisms differ, not only in appearance, but also in their power of response to conditions of the environment. If all moderating factors for a given organism are removed, the organism will thrive and produce tremendous numbers. On the other hand, if environmental factors are inhibitory, numbers will be small or totally absent. A set of conditions that are ideal for one organism may be lethal for another.

If changing conditions, such as pollution, are unfavorable, organisms must resist these changes, migrate or be destroyed. But, if conditions are favorable for certain organisms, these will thrive and build high populations. For this reason, the society of organisms found in zones of pollution is highly significant. It offers clues to the intensity of pollution and the degree of recovery.

Let it be supposed that the clean waters of the illustrative stream will provide suitable living quarters for a hundred different kinds of organisms, —a balanced society of plant and animal species (Figure 3-A). With the entry of sewage, the variety decreases rapidly. Of these 100 species upstream the majority find conditions for life unsuitable in the zones of pollution. It is only downstream in the recovery zone where biotic variety makes a gain.

Strange as it may seem, these few species in the pollutional zones find conditions quite suitable. Here they thrive in the absence of competition and with a high food supply. They are the ones that are intimately concerned with stream recovery. They may be called pollutional organisms.

If the biotic population be differentiated into clean water and pollutional organisms (Figure 3-B), their distribution may be contrasted. Bacteria are excluded from this graph. Clean water population drops abruptly to zero with the introduction of sewage. The population increases downstream with the variety increase. Pollutional population is low in clean water, but re-

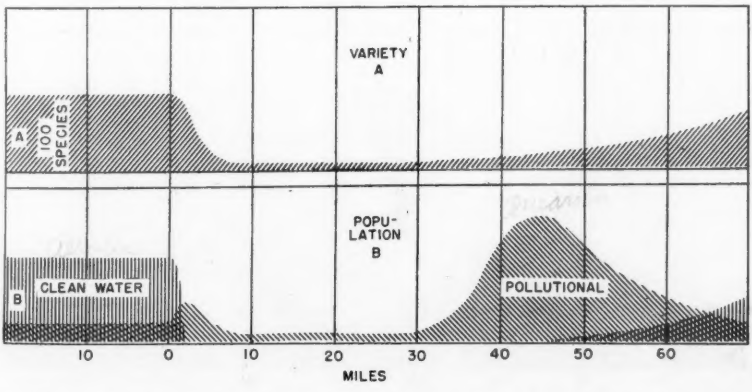

FIGURE 3.—Responses of bottom organisms to entry of raw sewage at zero mileage level. (A) Variety distribution; (B) population alterations of "clean water" and "pollutional" bottom forms.

sponse is quick in the presence of wastes. Even these organisms decline in the true septic zone where only the anaerobes can live. The population peak will occur near the 45-mile level where food is abundant and oxygen again sufficient for the biotic needs. In the absence of a septic zone, both population peaks would roughly coincide. This condition will apply also in the following graphs. Population drop from the 45-mile point reflects approaching exhaustion of the food supply.

Pollutional Organisms and Their Functions

Swimming about among the bacteria and creeping over the bottom sludge are minute animals composed of a single structural unit or cell. Some of these are able to utilize complex dissolved and particulate organic substances and in this way parallel the action of bacteria. Their prime function, however, is a more important one. They drive the bacteria and keep them at work. This is accomplished by the simple expedient of voraciously eating the bacteria so that they must reproduce to maintain their numbers. Since growth is a prelude to reproduction, biochemical oxidation proceeds at a feverish pace.

The bacteria-eaters are mainly those protozoans equipped with cilia which they use for swimming and food gathering. They move about continuously, lashing the water with their cilia and setting up currents that sweep bacteria into the gullet. This practice is carried out wherever bacteria occur. Following due process of ciliate digestion, the bacterial substance is now protozoan substance. The presence of bacteria and organic supplies results in a population peak below the bacterial peak as well as one above the septic zone (Figure 4).

But, for these protozoans all is not sublime—they too have enemies. As they are swept downstream or flutter

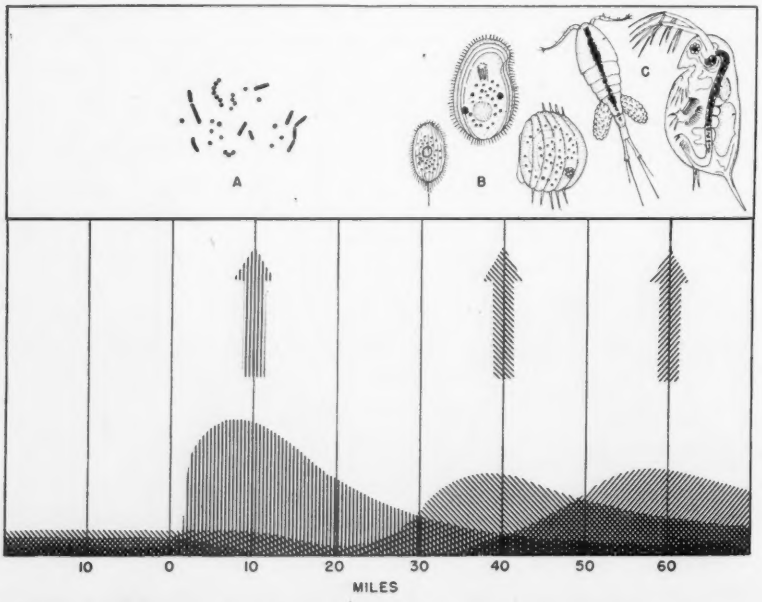

FIGURE 4.—Linear alterations in populations of bacteria, ciliate protozoans, and crustaceans.

over the mud, they finally fall victim to rotifers, water fleas and related crustaceans that select them for variety in their diet of bacteria and small algae. The peak crustacean population is at the 58-mile point (Figure 4). And so it goes, the larger eating the smaller until the food progression leads to mussels, crayfish, small fish and large fish.

Mainly restricted to the bottom is another array of biotic forms. These are perhaps the most dependable indicators of stream condition. Ordinarily, the pollutional bottom is a confusion of biological activity—each member of the assemblage going about his own business of gathering food and reproducing. To them, stream recovery is merely incidental. The distribution of species is governed by the stringency of habitat conditions.

Rat-tail maggots (Figure 5-A) are a sign of extremely poor conditions. Thus ugly larva of the drone-fly (*Eristalis tenax*) lies buried in the mud with the tail extended to the surface for air. For this reason, dissolved oxygen is not a consideration and it may penetrate into the septic zone.

Next in line come the sludge-worms (Tubificidae) (Figure 5-B), reddish in color, ½ inch to 1½ inch in length. They burrow in the mud where organic content is high. They excavate in the upper layers of the sludge, passing large quantities through the intestinal tract and straining out the food. With the posterior part of the body projecting into the water, the worms cast rejected parts of the sludge on the surface in the form of fecal pellets. The work accomplished in this manner is tremendous. The sludge is worked over, perforated and its organic content reduced.

Frequently these worms are so numerous that the stream bed appears as a red undulating sheet. They occupy the zones of degradation, active

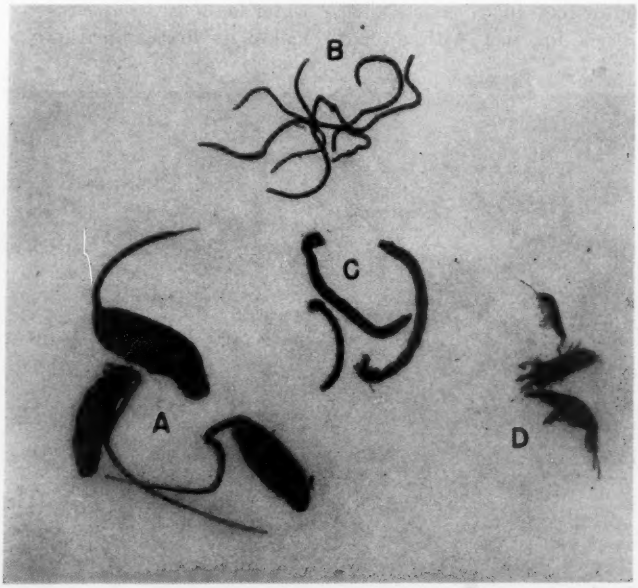

FIGURE 5.—Bottom organisms found in zones of pollution. (A) Rat-tail maggot (Eristalis tenax); (B) Sludge-worm (Tubifex sp.); (C) Blood-worm (Chironomus sp.); and (D) Sow-bug (Asellus communis). Approximately natural size.

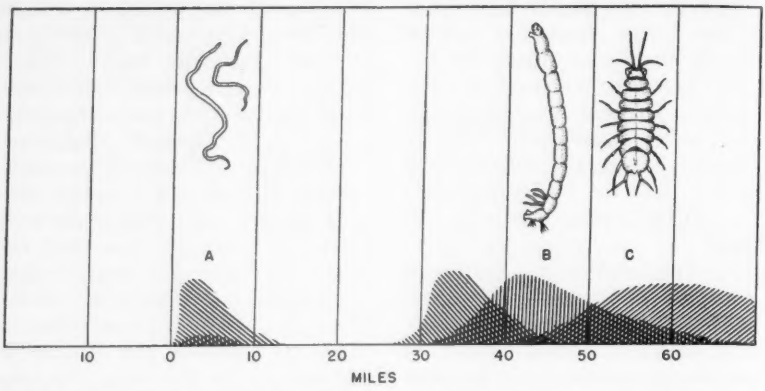

FIGURE 6.—Linear alterations in populations of sludge-worms (A), blood-worms (B), and sow-bugs (C).

decomposition and the upper part of the recovery zone. They are absent from the septic region.

Blood-worms (*Chironomus* sp.) also are burrowers in the mud. These are red, jointed, worm-like animals (Figure 5-C) that eventually transform to midge-flies. In this larval stage, they occupy burrow-like tubes constructed of sludge stuck together with an adhesive substance. Empty tubes are common and may occur in heaps. Their food habits are similar to the sludge worms, but they are more exacting in their habitat requirements. For this reason they reach their peak in the recovery zone.

At this point, also, the sow-bug or water-log-louse (*Asellus communis*) makes its first appearance. They are

FIGURE 7.—Sewage mold (*Sphaerotilus natans*) attached to sticks, stones and vegetation and waving in the current.

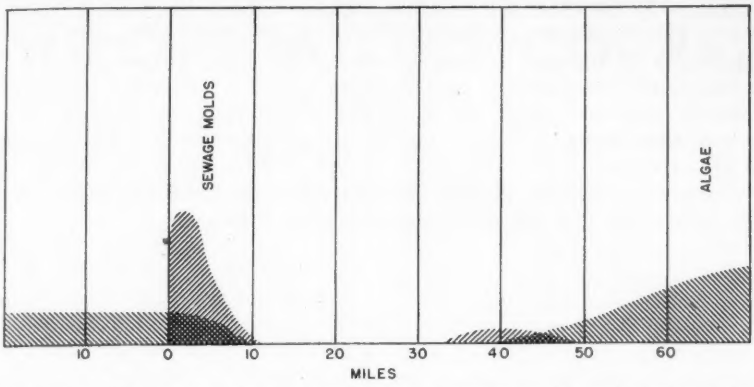

FIGURE 8.—Linear alterations in populations of sewage molds and plankton algae.

flattened, greyish animals about ¼-in. long (Figure 5-D), related to the scuds found in clean water. They are provided with jointed appendages, of which six pairs are modified as legs. They crawl about on the bottom, under stones, or climb among water weeds. They do not move by swimming.

Sow-bugs are omnivorous in their feeding habits but seem to prefer dead and decaying vegetable matter. Their oxygen requirements apparently are greater than those of sludge-worms or blood-worms. They are common in the recovery zone where dissolved oxygen in the supernatant water exceeds 40 per cent of saturation. They indicate improving conditions.

If the distribution of sludge-worms, blood-worms and sow-bugs are plotted together, their population peaks occur in the succession shown in Figure 6.

In addition to bacteria, other plants also are involved in stream recovery. Sewage molds and filamentous bacteria may be seen attached to sticks, stones and vegetation, waving gracefully in the current (Figure 7). They function with the bacteria in biochemical oxidation. They are whitish gray, becoming tinged with yellow, red or brown when old. In the zone of degradation, growth is widespread and luxuriant. It persists to the septic region and reappears feebly with oxygen restoration. Its presence is a reliable index of intense pollution—especially by carbohydrates.

The distribution of plankton algae, as a group, is in contrast to the sewage molds (Figure 8). The clean water population is reduced rapidly in the degradation zone where turbidity is high. They may be very sparse or absent throughout the septic region and then increase to a new high under the stimulatory influence of phosphorous and nitrogen compounds oxidized from sewage sources.

In the pollutional zones benthic algae may occur as a dark film over the bottom or as a bright green scum along the banks and in quiet spots. Most of these are filamentous, although some may be single-celled and able to swim. Some, at least, absorb certain organic solutions from the water. Valuable as this may be, the algae are more valuable for the oxygen they add to the water in the process of making food. They are instrumental in drawing up the lower end of the sag curve. They supply oxygen for the biochemical demand and speed the recovery process.

Summary

Living organisms are affected by the conditions of stream pollution. Their distribution is altered and may be used to complete the pollutional pic-

ture obtained by the usual testing procedures. Their activities contribute tremenduously to stream recovery by using pollutants as a source of energy and growth material. Some eat bacteria and thus accelerate their biochemical activities. Green organisms supply oxygen so greatly needed for B.O.D. satisfaction and sag curve elevation. Metabolic wastes, products and dead bodies are passed back to the stream as an altered link of a continuous chain. Biological efficiency in the stream falls far short of that in the treatment plant. A good treatment plant at Windmill would confine these activities and restore utility to the running stream.

SEWAGE TREATMENT IN NEW MEXICO

Sewage treatment practice in New Mexico is hardly typical of most other states, according to Charles G. Caldwell, Director of the Division of Sanitary Engineering, New Mexico Department of Public Health. In a paper given at the 1947 Annual Meeting of the Rocky Mountain Sewage Works Association, Mr. Caldwell pointed out that sparsity of population and climatic conditions in New Mexico create unusual problems, but also permit some practices that might not be allowable elsewhere.

There are only 63 incorporated areas in the state, of which only 5 cities have populations over 10,000 and 17 have populations between 2,500 and 10,000. These 63 municipalities in 1946 had a total population of 212,000, and they constitute the potential for the state in municipal sewage treatment. The population density in New Mexico is slightly under 4.4 persons per square mile.

Fifty of the 63 municipalities are served by sewer systems, and 46 by sewage treatment plants. Primary treatment is by Imhoff tanks in 20 plants, by septic tanks in 19 plants, and by separate sludge digestion in 7 plants. Secondary treatment is by contact beds in two plants and by trickling filters in fifteen. Effluent disposal in 16 cases is by discharge on land or to lagoons, in 10 cases by discharge to dry arroyos, and in only 22 cases by discharge to streams.

Most of the sewage treatment plants are in that part of the state where the climate is hot and dry. Artificial heat is usually not required at separate digesters, and the natural dry, sandy soil frequently suffices for sludge drying beds, without underdrainage. Waste land is plentiful and cheap, making it possible to isolate plants and to provide ample areas for screenings and grit burial and for sludge and effluent lagoons. Flat terrain and lack of streams often require the lagooning of effluents.

Because of the hot climate, biological activity is at a high rate, giving rise to hydrogen sulfide production in sewers, and to heavy trickling filter growths. Filter flies are a serious operating problem. Chlorination has been found effective in controlling these difficulties.

THE OPERATOR'S CORNER

CONDUCTED BY S. C. MARTIN

PAINT IS A VERSATILE TOOL

Paint is remarkable stuff! Ever since our ancestors of 50,000 years ago rudely splashed the dark interiors of their caves with crude pictorial records, paint has served mankind in many and varied ways.

Perhaps man's long climb up the ladder of civilization could be charted as well in the improved ways he learned to make paint as by his increasing ability to express himself by the use of paint. The crude mixtures of ground clays and juices of roots and berries contrast strikingly with the scientific and precisely compounded paint mixtures and dispersions in common use today. Crude or complex as the case may be, paint has served man well. It was his first and remains his greatest tool of spiritual self-expression. It helped to set him apart from the animals.

Paint has also made its utilitarian contribution to man, and it is this characteristic which has made paint such a valuable aid in sewage works operation. In innumerable ways paint has aided plant operation and increased maintenance efficiency. To most sewage works men paint is primarily a cover and a protection, applied to conceal the earmarks of use and time and to protect against the effects of wear, weather, and corrosion. This is as it should be, but paint can do far more than cover and protect.

Paint can identify. When this practical characteristic is efficiently utilized mazes of small-pipe layouts become intelligible to both operator and visitor. Dangerous areas can be made literally to shout their warning. Protruding ledges, low overhead pipes and beams, unexpected steps or curbings will draw deserved attention when spotlighted by a bright contrasting color.

Paint can beautify. Beauty is not often associated with sewage works but the tasteful use of colorful paints can contribute much to the attractiveness of any plant. No building, structure, or equipment is too old or too shabby to be made more attractive by intelligent painting. Many beauty spots of form, contour, or texture now hidden, could be revealed by the magic touch of the proper paint. The cheerfulness and lift in a colorful paint job are proven protection against monotony and gloom. Paint, teamed with light, can provide a daily tonic of considerable value.

Paint can reveal. As a mirror of an operator's personality it has few equals. A half-hour's observation of a man on the business-end of a paint brush will reveal more than many of the so-called psychological yardsticks. And a careful noting of the use of paint—or lack of it—at a sewage works may tell more about plant operation than an examination of voluminous operating records. Each man paints his portrait as he paints his plant!

There is more to painting than the spreading of diluted pigment on a surface. Intelligent selection of a suitable paint and a working knowledge of modern paint properties and methods are essential if a paint job is to serve all of its purposes and return solid dividends on the money and effort invested.

S. C. M.

CHLORINATION OF SEWAGE*

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Many papers have been written on the chlorination of sewage, and quite often under this same general heading. All have agreed that the primary use of chlorine in sewage treatment is for disinfection. Most have mentioned several other uses of chlorine. Few have emphasized, under a single heading, these other uses of chlorine to any level of practicability. In an operational paper such as is intended here, the latter is essential. Almost every chlorine use in a treatment plant, other than disinfection, is for the purpose of solving some particular problem confronting the superintendent or operator.

An admirable basis for a classification of the uses of chlorine in sewage treatment is found in a recent article by Enslow and Symons (1). They state that by definition there are only three processes of sewage treatment, namely, primary treatment, secondary treatment, and disinfection. Sludge disposal is merely a byproduct process.

To apply chlorine to this classification is a simple matter. Chlorine in sewage treatment for disinfection stands alone. Most of the other uses of chlorine in sewage treatment deal with its application for solving troubles with, or benefiting, the other two processes. From an operational viewpoint, it is with these processes, and the use of any chemical as an adjunct thereto, that the superintendent and operator are fundamentally and vitally concerned.

Development of the Use of Chlorine

The growth of chlorination in sewage treatment is contained in a 1946 survey (2) of sewage plants. Of a total of some 5,400 sewage plants, 1,320 were found to be using chlorine for one purpose or another. This represents a 30 per cent increase in the number of plants using chlorination in the last eight years. This growth can be attributed, to a large extent, to the use of chlorine for disinfection in the slightly more than 1,000 sewage plants built during the war period. This growth is also due, without doubt, to the continued expansion in the use of chlorine as an adjunct of primary and secondary treatment. Odor control uses are among the most significant.

Of 297 sewage plants in Pennsylvania, 139 were found to be using chlorine. Pennsylvania has the same number as New Jersey, and both are exceeded only by New York state, with 172 plants using chlorine. In the percentage of plants using chlorine, Pennsylvania with 46.5 per cent ranks fourth, being exceeded only by New York with 52 per cent, Louisiana with 51.8 per cent, and New Jersey with 51.1 per cent.

Chlorine for Disinfection

History

Chlorine was first used for the disinfection of sewage at Hamburg, Germany, in 1893. The first recorded use of chlorine for this purpose in the United States was a year later, at Brewster, N. Y., where A. E. Woolf obtained chlorine in the form of sodium hypochlorite by electrolyzing a strong brine solution. This hypochlorite was applied to the sewage for disinfection purposes to protect the Croton Reservoir water supply of New York City.

* Presented at the 21st Annual Meeting, Pennsylvania Sewage and Industrial Wastes Association; State College, Pa.; August 25–27, 1947.

In 1906 and 1907, Phelps, with the aid of others, studied the use of chlorine for the disinfection of sewage at Boston, Baltimore, and Red Bank. The use of chlorinated lime at the latter plant, by Phelps and Daniels, marked the real beginning of chlorination for sewage disinfection in the United States.

After liquid chlorine came into use in 1914 for the disinfection of sewage at Altoona and Milwaukee, its use at other plants followed in rapid order. Soon the United States obtained a lead never relinquished. Today, more plants in the United States use chlorine for sewage disinfection, or for that matter for any other purpose, than anywhere else in the world.

In the fewest possible words, the purpose of chlorination for sewage disinfection is to prevent bacterial contamination of (1) streams or other receiving bodies of water used for public water supplies, (2) the shell-fish industry, and (3) recreational areas such as those used for bathing.

Application Points

From an operational standpoint, it is important to mention that Tiedeman and Enslow established that when a high degree of disinfection (effective disinfection) was needed, it was necessary to maintain a slight chlorine residual after a contact or detention period.

If primary treatment is the only treatment process at the sewage plant, the proper detention period for disinfection can best be afforded by prechlorination ahead of the settling basin. Occasionally, postchlorination of the settling basin effluent ahead of a long outfall sewer will afford the proper contact time.

If secondary treatment is used at the sewage plant, the proper detention period can be obtained by postchlorination ahead of the final settling basin, ahead of a chlorine contact chamber, or ahead of a long outfall sewer.

Residual Requirements

As a rule, the amount of chlorine residual that must be present in the sewage after a given contact period in any of the treatment units mentioned above depends upon the local state health department requirements. Whatever the regulations, the superintendent or operator should be aware of them and see that they are followed as rigidly as is practically possible. State board of health requirements appear to cover the range of 0.2 p.p.m. chlorine residual after a 5-min. contact period to 1.0 p.p.m. chlorine residual after a 30-min. contact period. On the average this requirement is not far from a 0.50 p.p.m. chlorine residual after a 15-min. contact period.

Dosage Requirements

The amount of chlorine required for sewage disinfection will depend upon several factors, including the state health department requirements. Compliance with a certain chlorine residual after a given contact period is merely satisfaction of the chlorine demand of the sewage. The one important factor, therefore, is the chlorine demand of the particular raw or treated sewage to be disinfected. For raw sewage the amount of chlorine required for disinfection usually varies from 10 to 20 p.p.m. For highly septic raw sewages this figure can be as much as 40 p.p.m. The chlorine requirements for disinfection of secondary treatment effluents vary from 6 to 12 p.p.m. for trickling filters, 3 to 6 p.p.m. for sand filters, and 2 to 4 p.p.m. for activated sludge plant effluents.

During sewage disinfection studies at Buffalo, Symons, Terhoeven, and Torrey (4) found that the chlorine required for adequate disinfection of a raw domestic sewage was 0.005 lb. of chlorine per capita per day. At one Pennsylvania sewage plant employing prechlorination ahead of settling for disinfection and receiving a fresh,

strictly domestic sewage, the figure was 0.006 lb. of chlorine per capita per day. When industrial wastes are present the figure will be higher. In actual plant operation at Buffalo, the figure, as a result of industrial wastes in the sewage, increased to 0.010 lb. of chlorine per capita per day. Whether industrial wastes are present or not, these figures may in time prove to be a reliable estimation of the chlorine requirements for disinfection.

Dosage Control

Control of chlorination for disinfection consists usually of checking chlorine residuals with the ortho-tolidine or the thiosulfate starch-iodide test, and then resetting the manually controlled chlorinator when indicated. Automatic solution feed type chlorinators are used to a limited degree in sewage treatment. The latest development, and one more applicable in all respects, consists of a program chlorinator which permits the application of chlorine to more nearly conform with the changing total chlorine requirements caused by changes in volume and chlorine demand. The program arrangement permits adjusting the chlorine applications each hour.

The number of residual determinations and resettings of a manual chlorinator required daily depends upon the size of the sewage plant. In the large plants where economy is an item, accurate control is essential. Whatever the frequency of control tests and chlorinator adjustments may be, they must be adequate to maintain not less than the required chlorine residual at all times.

At small plants proper control may be provided by determining the chlorine residual once a day, at the time when the maximum chlorine requirements may be expected, and then resetting the chlorinator as the test indicates. If the chlorinator is reset, another chlorine residual should be taken after the proper lapse of contact time. Both chlorine residuals, not just the last, should be reported on the daily log. Based on experience, it is advisable to have two regular chlorinator settings—one for the day flow and one for the night flow.

At larger plants the chlorine residuals should be taken every hour or every two hours during the daytime. Chlorinator resettings should be made frequently. A curve showing poundage of chlorine per unit volume of sewage flow versus time for the daytime hours for each day of the week is of inestimable value in arriving at the proper chlorinator settings throughout the day. Often a set of figures in lieu of the curve serves equally well, for then it is an easy matter to readjust the figures for use during the following week.

This practice was adopted at one Pennsylvania sewage plant. Prior to the use of daily chlorine poundage cards, 10 per cent of all of the chlorine residuals taken hourly between 8:00 A.M. and 5.00 P.M. were zero. After the card system was put into effect, only 4 per cent of the chlorine residuals taken hourly were zero.

At the largest plants where the personnel is adequate and well equipped laboratories are available, the control of chlorination is considerably more accurate. For example, at both Buffalo and Los Angeles close checks on the chlorine dosages are maintained by taking hourly chlorine demand tests.

Chlorine as Adjunct to Primary Treatment

Odor Control

Odors were a problem in sewers and receiving streams long before they were ever thought of as a problem at sewage treatment plants. In 1777 sewer gases in Paris caused several deaths. In 1806, some 29 years later, a committee came to the conclusion that these deaths had been due to hydrogen sulfide.

Several decades later, the Royal Sewage Commission of Great Britain recommended that the London sewage be chlorinated for odor control by using bleaching powder. Dibden put this recommendation into effect in 1884. Thus, by this event chlorine compounds came to be used for odor control before they were used on a practical basis for disinfection.

In 1912, Ellms and Waring of Ohio tried chlorinated lime for odor control on a septic tank in Cincinnati. Cleveland became one of the first cities to chlorinate sewage in an outfall sewer for the purpose of controlling odors. With the advent of the Imhoff tank the use of chlorine for odor control received considerable impetus. By 1930 (6), 50 plants in the United States were listed as using chlorine for odor control. Since then, the number of plants using chlorine for this purpose has expanded rapidly.

In this country the control of odors today is usually the number one problem of sewage works superintendents and operators. There are odors at every plant but the degree of their intrusiveness and obnoxiousness varies widely. The problem has been more acute in recent years with the tendency to situate sewage plants nearer cities and towns and along the main arteries of travel. An example of this is the location of a sewage plant on Long Island. There, 30 cottages are located within 1 to 25 ft. of the plant site. As the sewage plants become more critically located, the number of odor complaints is bound to increase. It is the responsibility of the superintendents and operators to satisfy all legitimate complaints and develop good will. Lawsuits are costly.

The purpose of odor control is to prevent odors from forming or reduce those already present below a level objectionable to the population. Many compounds in sewage, including such derivatives as indole and skatole, cause odors at sewage plants. By far the most serious odors are those of hydrogen sulfide. It has been said that one can detect hydrogen sulfide in air in concentrations as low as 0.000001 p.p.m., but experience has amply shown that 0.8 to 1.0 p.p.m. can be present in sewage settling basins without causing complaints.

From an operational standpoint, it is important to mention that Heukelekian (7) showed the chlorine application for effective odor control to be definitely related to the chlorine demand of the sewage and the degree of hydrogen sulfide production. The author found that a minimum of 20 to 25 per cent of the chlorine demand of the sewage should be satisfied in order to keep the sulfide content below 1.0 p.p.m. for a reasonable period. In practice it has been necessary, in some instances, to satisfy as much as 50 per cent, or slightly more, of the chlorine demand to obtain effective odor control. Hydrogen sulfide theoretically takes 2.22 p.p.m. of chlorine for each p.p.m. of sulfide. In practice, 3 to 15 p.p.m. of chlorine has been found necessary for the destruction of each p.p.m. of sulfide due to the immediate demand of other compounds in the sewage for the chlorine.

A recent and rather comprehensive article (8) on the subject of hydrogen sulfide formation is mentioned because it has a direct bearing on the operational angle of odor control. It appears that hydrogen sulfide formation is not particularly dependent upon the age of the sewage or the sulfate concentration of the sewage. Hydrogen sulfide production increases with increasing temperature, with increasing strength of the sewage, with decreasing pH of the sewage, and with decreasing velocity of flow. It is important to note in this instance that the hydrogen sulfide came from the slimes on submerged surfaces of the sewers and from deposited sludges in the sewers. On this hypothesis, odor control becomes a question of slime control.

If odors are present in the sewage on its arrival at the sewage plant, the sewage should be chlorinated, if at all possible, at a distant pumping station, trunk sewer, or intercepter. At some plants it is structurally possible to chlorinate only at the plant, as prechlorination ahead of settling.

The importance of up-sewer chlorination cannot be overemphasized. Up-sewer treatment has the advantage of preventing sewer deterioration due to sulfuric acid formation. Disintegration of concrete conduits and mortar joints can prove costly. Considering odor control as slime control, the advantage of up-sewer chlorination becomes obvious. Besides any other consideration that might be given to the sewers, up-sewer chlorination is preferable to prechlorination at a plant receiving sewage with hydrogen sulfide odors. Prevention is more economical than removal.

If the sewage is rather fresh on arrival at the plant and it is definitely established that the odors are being produced in the primary treatment units, Imhoff tanks being a recognized offender, then prechlorination at the plant as prevention control should be practiced. In such cases it is advisable to apply the chlorine, if practical, ahead of the screens or the grit chamber to obtain overall odor control in the primary units.

Chlorine for odor control is usually fed seasonally or continuously, depending upon local conditions. Control is obtained by applying enough chlorine to satisfy 25 to 50 per cent of the chlorine demand. This means 25 to 50 per cent of the amount of chlorine required for sewage disinfection. For prevention control, less chlorine will be required than for removal control because the latter is often coincident with a highly septic sewage.

When up-sewer chlorination for odor control is to be considered as slime control, it may be advisable to destroy the sulfides completely. Under such circumstances the chlorine requirements will be the 3 to 15 p.p.m. of chlorine for each p.p.m. of sulfide, as stated above. However, the chlorine needed will be less than that required to satisfy the chlorine demand.

The control of the amount of chlorine that must be used for effective odor control is more difficult than the control of sewage disinfection due to the fact that there is no chlorine residual to chlorinate to. The actual amount of chlorine that has to be used can be determined satisfactorily at plants having well-equipped laboratories by making frequent or occasional sulfide tests. Such tests show if the sulfide is being held below the maximum allowable limit of 0.8 to 1.0 p.p.m. A modified methylene blue test (9) has been successfully used for the control of odor. Lacking either test, and this is commonly the practice in the small plants as well as many larger ones, the number of complaints received is the criterion of adequate control.

This brings to mind the story (10) of Homer Fisher at Benton, Illinois. He keeps grimmacing into a mirror. He has several silver fillings in his teeth. When the fillings turn black, he then knows it is time to start prechlorination for odor control. This brings to attention an important fact. Odor control regulated by smell alone is an unsatisfactory method of control. The nose soon becomes insensitive to the continued presence of hydrogen sulfide.

Effective odor control can also be obtained by the use of iron salts made by treating scrap iron with chlorine. It is an economical method, particularly when the sulfide content of the sewage is extremely high or when a highly septic sewage is encountered. Mixtures of ferrous and ferric iron are reported to be more effective than either alone. They appear to be most effective when the solution contains about two-thirds ferric iron salts.

Plant Overload

Overload may be due to exceeding the designed capacity of the plant, to the presence of industrial wastes in the sewage, or to the return of too much supernatant overflow to the raw sewage. The first is volume overload, the latter two are organic overloads. All three are related to B.O.D.

Chlorination of sewage for any purpose reduces the B.O.D. and hence the load on the plant. When up-sewer or prechlorination is used for odor control, the load on the plant will be less because the B.O.D. is being reduced at the same time. When prechlorination ahead of settling is being used for disinfection, the load on the primary and secondary units will be less, because chlorination has been carried still further and the B.O.D. reduced still more. Obviously, there is a limit to correction with chlorine when volume overload reaches a certain critical point.

In using prechlorination for reducing plant overload, each p.p.m. of chlorine will reduce (11) the B.O.D. approximately 2 p.p.m., *i.e.*, for each pound of chlorine applied, the B.O.D. will be reduced by about 2 pounds. This rate of reduction is fairly constant up to the point where a chlorine residual, as in sewage disinfection, is obtained. By the time the chlorine is added in sufficient amount to produce this residual, the B.O.D. load on the plant is reduced by 15 to 35 per cent. This reduction is most significant with strong sewages, highly septic sewages, sewages containing industrial wastes, and when supernatant is being returned to the raw sewage. It is uneconomical to chlorinate beyond the point necessary to obtain a chlorine residual. Beyond that point the amount of chlorine required to give a comparable B.O.D. reduction becomes excessive.

The use of prechlorination for reducing plant overloads has often exceeded expectations. One of the most outstanding instances is that reported by Rawn (12) several years ago. Septic sewage was reaching an activated sludge plant and as a result the sewage would not respond readily to secondary treatment. Chlorination of the raw sewage produced a fresh sewage at the plant and its capacity was thereby trebled.

At Butler, Pa., Haseltine reported (13) how changing from postchlorination at the primary units to prechlorination produced greater B.O.D. removal through one clarifier than previously was obtained through the use of two clarifiers in series.

Grease Removal

Grease is a problem at many sewage plants. Mahlie (16) says that grease occurs in sewage in larger quantities than is usually suspected and that its effects are more far reaching than is admitted.

Gascoigne (17) as early as 1931 reported that chlorine applied to sewages or industrial wastes high in grease would break up the emulsions allowing the grease to float, thus facilitating its collection. Superintendents and operators have noted this for years and on rare occasions have reported their observations. Most of the observations have followed the same general pattern. Prechlorination was found to increase the amount of scum removed form the surface of the settling tanks. It did not result in more frequent skimming. Actually the scum appeared to accumulate in a more dense or compact mass requiring less skimming and resulting in an improved general appearance of the settling basins and clarifiers.

In 1937, Faber (14) reported the first use of chlorine with diffused air, a process called aero-chlorination, at Woonsocket, R. I. Wiest (15), in 1938 at Lancaster, Pa., modified the procedure by applying chlorine solu-

tion to the sewage ahead of the aerators.

The reasons for which grease may be removed, partly as scum and partly as sludge from various settling processes, are several fold. The number of adverse effects it may have on sewage plants has been ably listed by Mahlie (16). It blinds screens, accumulates on walls, destroys the paint on steel structures, gives rise to odors, interferes with Imhoff tank performance, interferes with secondary treatment, clogs filters, and interferes with sludge digestion.

Chlorine for grease removal can be applied as prechlorination ahead of a preliminary skimming tank, ahead of a settling tank, or ahead of aeration tanks. Aero-chlorination may also be employed in which case dry chlorine gas is mixed with the diffused air going to the aeration tanks.

If chlorine is applied to the sewage as prechlorination, it is not necessary to chlorinate to a residual to obtain further removal of the grease. Often as little as 2 to 5 p.p.m. of chlorine will suffice.

If aero-chlorination is employed, it is general practice to use 2 to 10 p.p.m. of chlorine as chlorine gas and 0.02 to 0.20 cu. ft. of air per gal. of sewage, with a 3 to 20-min. aeration period.

Improved Clarification

When prechlorination has been used for disinfection, odor control, plant overload, or grease removal, many superintendents and operators have found considerable improvement in the clarification of the primary tank effluents.

Cohen (18), in 1928, was among the first to report on this effect. At the Lufkin, Texas plant, prechlorination ahead of the Imhoff tank resulted in a tank effluent containing less suspended matter. Others have reported the same effect. In recent years, the use of prechlorination has been reported to have improved the settling rate at the sewage plants at Annapolis, Md., Clearwater, Fla., Kankakee, Ill., and Racine, Wis.

The purposes of using chlorine for improved clarification are (1) to improve the settling rate of normal sewages, (2) to overcome the septicity of raw sewage and thus keep the sludge from rising in the clarifier, (3) to increase grease removal and thus overcome the adverse settling effect grease has on the suspended matter, and (4) to aid in chemical precipitation processes.

As regards the rising of sludge in clarifiers, Jones (19) in a recent article points out that septic sewage and industrial wastes are the worst offenders. The buoyant effect of suspended solids containing gaseous decomposition products causes the solids to rise, or at least retards their settling rates, so that the solids are carried out in the effluent.

Prechlorination applications of as little as 1 p.p.m. of chlorine will increase the settling rate of a normal sewage, and for septic sewages as little as a 2 p.p.m. application has given some improvement. When industrial wastes are present and are adversely affecting the settling rate, considerably higher applications of chlorine are required. The amount depends upon the particular wastes involved and may be several p.p.m.

The use of chlorine as an aid to coagulation or chemical precipitation is not confined to sewage treatment alone. Prechlorination has been of aid to coagulation in water treatment for many years. At Butler, Pa., Haseltine (20) found that the addition of chlorine was a necessary adjunct to chemical coagulation of sewage when using iron salts. The same observation is on record at the Shades Valley plant at Birmingham, Ala.

Decreasing Load on Stream

The primary purpose of a sewage treatment plant is to lower the B.O.D.

and bacteriological load delivered to the receiving stream.

The use of chlorine for relieving the load on the stream is particularly applicable at sewage plants employing only primary treatment. It is a desirable adjunct with primary treatment at those times of the year when stream flows are insufficient to give proper dilution. It should not be inferred from this, however, that chlorination for this purpose is by any means a substitute for secondary treatment.

The most common practice for decreasing the load on the receiving stream appears to be prechlorination ahead of settling in which case the B.O.D. is reduced as mentioned under the subject of plant overload.

Postchlorination of the primary effluents is not excluded as a use of chlorine for this purpose. It has been used with considerable success, and B.O.D. reductions of as much as 50 per cent have been reported, although with primary effluents the reduction normally is not expected to exceed 25 to 35 per cent.

Chlorination sufficient to produce a residual at the point where the sewage effluent enters the stream is usually advisable. The report of the A.P.H.A. Committee on Sewage Disposal (11) states that chlorination sufficient to produce a chlorine residual in the stream receiving the chlorinated sewage or effluent will retard the normal decomposition processes and will tend to prevent anaerobic conditions during normally critical periods of rapid oxygen depletion. It permits an opportunity for reaeration and additional dilution from tributary streams to maintain aerobic conditions. The committee warns, however, that the effect of chlorine carried in sewage effluents may be negligible in streams containing extensive sludge deposits.

Other than reduction in the B.O.D. load on streams, the reduction in the bacterial load is of utmost importance. The primary treatment plants at Buffalo and Detroit are the largest plants in the United States using chlorine for this purpose. Both use prechlorination.

These plants are correctly interested in keeping the number of bacteria in the sewage effluent down to a certain specific level. Unfortunately, most bacteriological results obtained at sewage plants have been reported as percentage of bacteria removed within the plant rather than the number of bacteria remaining in the effluent. It cannot be overemphasized that it is the number of bacteria per unit volume of sewage discharged to a stream and not the percentage of bacterial reduction in the plant which determines the quality of the receiving stream.

Chlorine as Adjunct to Secondary Treatment

Trickling Filter Odor Control

Odors have always been a problem in the operation of trickling filters. For one reason or another, the odors from trickling filters appear to be more offensive to a citizen than the odors from primary units. It appears that there have been more damage suits resulting from trickling filter odors than from those of primary treatment units. At least one city in the United States has had as many as 25 to 30 lawsuits as a result of odors from trickling filters.

In 1911 (21) bleaching powder was used at Stratford-on-Avon in England for controlling odors at trickling filters. Three years later this plant moved the point of application to the crude sewage and thereby was able to eliminate odors throughout the plant.

Enslow, of the Chlorine Institute, in the late twenties and early thirties was particularly active in giving assistance to plant superintendents and operators in eliminating odor problems at sewage plants, including the odors at trickling filters.

Cohn (22, 23), at Schenectady, was one of the first plant superintendents in the country to experiment with the use of chlorine for controlling odors at trickling filters. Washington, N. J. (24) was among the earliest plants to apply chlorine at the dosing tank for odor control at the trickling filters.

The object of using chlorine for odor control at trickling filters is to eliminate the nuisance of odorous gases released from the spray and, occasionally, from the filters.

Chlorine for the control of odors at trickling filters is fed seasonally or continuously, depending upon plant conditions and the proximity of the plant to nearby residences or highways. Two procedures in the application of chlorine appear to be acceptable. The chlorine may be applied either as prechlorination ahead of the settling tanks or as primary treatment postchlorination to the primary effluent on its passage to the dosing tank.

Control usually is obtained by applying enough chlorine to satisfy 10 to 20 per cent of the chlorine demand. In a few cases as much as 100 per cent of the chlorine demand must be satisfied. The amount of chlorine required at most plants seems to vary from 2 to 6 p.p.m., the quantity naturally being dependent to some extent on whether the chlorine is being applied to the primary tank influent or effluent. Recirculating part of the plant effluent is sometimes an effective way of reducing the chlorine requirements.

As mentioned previously, the control of chlorination when not chlorinating to a residual is often more difficult than in those cases where a residual is required. The most common criterion of the proper amount of chlorine to be used is the number of complaints received. Some plants do not like to rely on this type of control, because, if something goes amiss, a considerable amount of good will can be lost.

Some plant superintendents or operators have effected control by adding sufficient chlorine to the primary effluent to produce either a small chlorine residual or a small amount of dissolved oxygen in the sewage at the spray nozzle or distributor.

When the odor nuisance is from the filter itself, chlorination of the sewage has not always been effective, particularly where spray nozzles are used, due to incomplete coverage of the filter surface. In such cases, spreading chlorinated lime or hypochlorite over the surface has been extremely effective. Hirsch (25), in a recent article, reports that an application of about 10 lb. of dry hypochlorite per 1,000 sq. ft. of filter area is quite satisfactory.

At Lebanon, Pa., Beamsderfer (26) applies 2 p.p.m. of chlorine to the Imhoff tank effluent for odor control at the trickling filters. He occasionally makes a dissolved oxygen test. When he finds none, he starts recirculation of the secondary effluent. This procedure has resulted in very effective trickling filter odor control.

Filter Pooling Control

Filter ponding or pooling has been experienced at several trickling filter plants. Many superintendents and operators consider this an embarrassing situation and more so when they have to resort to a drastic chlorination practice. At some plants this pooling occurs regularly in the late winter or early spring. Others fortunately have never had this trouble, but since it may occur unexpectedly at any time, it is well for superintendents and operators to be acquainted with the steps that should be taken for its correction.

The purpose of using chlorine for the relief of a ponded filter is to remove the clogging, which is usually in the upper 8 to 16 in. of the filter, due to sewage solids, organic growths and, at times, algae.

Filter ponding is controlled by measures that may be described as removal or prevention.

Control by removal is afforded by

chlorination in two ways: (1) by applying chlorinated lime or dry hypochlorite on the surface of the filter, or (2) by chlorinating the filter influent. If chlorination is restored to, it should be applied at night when the chlorine demand and flow of the influent are at their lowest. An adequate chlorine residual, the secret of effective relief, is thus obtained at a considerable saving in chlorine.

The amount of chlorine required for the relief of filter pooling is usually expressed as p.p.m. of chlorine applied, or as lb. of chlorine per 1,000 sq. ft. of filter area. If hypochlorite is used, the application required will likely be about 8 to 12 lb. of available chlorine per 1,000 sq. ft. of filter. If the influent to the filters is chlorinated, the amount of chlorine required must be sufficient to give a 2 to 10 p.p.m. chlorine residual at the nozzle. This may require anywhere from 5 to 30 or 40 p.p.m. of chlorine. Whatever the practice may be, chlorination is continued nightly until the filter ponding has been relieved. It may take 2 to 6 successive nights before the relief is complete.

Control by prevention is usually practiced at those plants periodically plagued with filter pooling. To insure permanent relief, many of these plants have set up a chlorination program which experience has proven to be highly beneficial. Chlorine is sometimes applied to the filter influent continuously or semicontinuously in moderate doses. Chlorination may be programmed so that it is applied 1 day a week at 2-hour intervals or 1 night a week from possibly 8:00 P.M. to 8:00 A.M., or any other combination. If such a programmed procedure is followed, the dose should be moderate but sufficient to maintain a 1 to 2 p.p.m. chlorine residual at the nozzle.

In the control of filter ponding, it is sometimes necessary to take extremely drastic action. Although not recommended, the case at Westfield, N. Y. (27) can be cited. To get rid of the ponds on the filter, it was found necessary to run the chlorinator hose to the filter and spray the chlorine water directly on the surface of the filters with the chlorinator running at its full capacity of 200 lb. per day. The treatment inactivated the filter for about 5 weeks. Under more normal treatment the filter effluent is usually of satisfactory quality in a week or so after the ponding is relieved. Many plant reports show that the effluent, in returning to normal, is of far better quality than it had been for months previous to the ponding.

At Butler, Pa. (28), heavy chlorination of the final settling tank effluent and recirculation of this effluent would not, under normal operation, relieve a filter ponding condition. Ponding was finally eliminated by pumping chlorinated effluent to the filter influent and having an operator hold the distributor arm in one place for about 30 min., then rotate the arm 10 ft., and repeat the performance until the filter had been completely treated in this manner.

Filter Fly Control

Psychoda alternata are a nuisance at many trickling filter plants, particularly to the plant personnel. Prevention of the nuisance is preferable to trying to reduce the number of the flies after the situation has become almost unbearable. It must be admitted that this is not as simple as it sounds.

Many plant superintendents and operators do not like to use chlorine for this purpose for fear that such chlorination will harm the operation of the filter. Yet, if chlorination is adequate to remove some of the organic growths in the upper layer of the filter, it is reasonable that the breeding ground for the psychoda fly will have been considerably minimized.

In controlling the filter fly, chlorine is applied to the filter only during the fly season. Chlorination is programmed

during night flows when the amount of chlorine required to obtain a chlorine residual is at a minimum. Chlorine is applied to the filter influent 1 night every 10 days, 1 night a week, or possibly 1 to 2 successive nights a week. The frequency of the treatment is determined by experience at each particular plant.

The amount of chlorine required for fly control is less than that used for the relief of ponded filters. The application should be sufficient to give a slight chlorine residual at the spray nozzle; 3 to 10 p.p.m. of chlorine will usually be required.

At Perkasie, Pa., a 0.5 m.g.d. plant, chlorine is applied to the filter influent from 6:00 P.M. to 6:00 A.M. 2 to 3 successive nights every other week. Chlorine requirements seldom exceed 15 lb. per night, and the results are very effective.

Filter Improvement

When chlorine has been used for trickling filter fly and odor control, the personnel at the plants have invariably noted, and in some cases reported, how chlorination kept the filters cleaner than they had ever been before; how the pipe lines were cleaned of growths; how the spray nozzles were much cleaner than before; how, for the first time algae growths were kept off the filters; and how much the appearance of the filters was improved.

Chlorination for trickling filter odor control and for psychoda fly control is good operation practice. In some cases, the quality of the trickling filter effluent is maintained at a higher level than before. At more than one plant, from the standpoint of operation, the sloughing of material from the filter has been even of more importance than odor control, the original intention of the chlorination.

Activated Sludge—Sludge Bulking Control

In 1926, De Laporte, of the Ontario Provincial Health Department, applied a solution of bleaching powder to return sludge to correct disturbances at activated sludge plants giving inferior effluents. At the Barnsley, England activated sludge plant, Bell (19) in 1929 reported plant improvement by applying bleaching powder to the raw sewage prior to sedimentation. He derived even greater benefits by a secondary application of chlorine to the return sludge at the point of mixture of the return sludge with the settled sewage. Gascoigne (6), in speaking of this plant, states that after this treatment was put into practice the Barnsley plant took care of the load for the first time without bypassing the secondary units, and the quality of the effluent was improved.

In 1934, Smith at Lima, Ohio (30, 31), at the suggestion of Purdy, tried chlorination of the return sludge during a period of bulking and found that small amounts of chlorine effectively reduced fungus growths and stopped the bulking. As early as this it was found that the amount of chlorine required was governed by the percentage of solids in the return sludge. In November, 1935, Lancaster, Pa. successfully added chlorine to the return sludge to remedy a sludge bulking condition. Other plants soon followed in rapid succession. The Radnor-Haverford, Pa. activated sludge plant was among the early users of chlorine for this purpose.

The role of chlorine in activated sludge bulking control has been variously explained. Chlorination undoubtedly kills part of the biological life in the return sludge. Tapleshay best expresses it by stating that he believes the chlorine restores the balanced load between the organic matter and the biological life present in the sludge.

The best procedure for sludge bulking control is that outlined by Tapleshay (32, 33) after visiting 50 activated sludge plants in the United States. Briefly, the procedure is to

apply chlorine to the return sludge at least two minutes ahead of where it mixes with the primary effluent; to use chlorine in an amount computed from the Tapleshay formula; to keep the rate of return sludge as near a constant percentage of the flow as possible during chlorination; and to seldom adjust the chlorine dosage day by day. The reason for the latter is that as the sludge index decreases the concentration of the return sludge increases as it becomes more compact. Chlorination is continued until the sludge index returns to the normal value for that particular plant.

In applying chlorine to the return sludge, the effluent usually gets turbid in the first 12 hours as the reaction sets in. This fact has caused some who have tried chlorination to discontinue the treatment and call it a failure. If chlorination had been continued, they would have found that the turbidity gradually decreased, along with the sludge index. Usually a decided improvement is noted in 3 or 4 days. Chlorination for sludge bulking is usually discontinued in 7 to 10 days.

The amount of chlorine required to control sludge bulking increases with the suspended solids concentration and with the sludge index. Tapleshay's chart (33) covers a wide range of values for these two figures which make use of anywhere from 2 to 24 lb. of chlorine per 100,000 gal. of returned sludge. Normally, the amount of chlorine required will vary between 2 and 8 p.p.m., with an average of 5 p.p.m., based on the return sludge flow.

Activated Sludge—Diffuser Plate Cleaning

The clogging of air diffuser plates in aeration tanks at activated sludge plants has, at some plants, become a major problem. Roe (34) in a paper published in 1934 described the causes of clogging and summarized the various practices used for cleaning the plates. Chlorine treatment is mentioned among the various procedures. Franklin (35) and Jackson (36) have reported on the use of chlorine, given details of the method, and have concluded that the use of chlorine is an effective and economical method of cleaning the plates.

Chlorine is added directly into the air header, one unit at a time. The usual practice is to use intermittent applications of chlorine, about 3 or 4 lb. per hour for about 2 to 3 hours during the day. Continuous treatment will require about 12 to 15 lb. of chlorine.

The use of chlorine for cleaning diffuser plates does not give continuous relief but, if used properly, it should not be necessary to remove the plates for cleaning more often than every 2 years or so. Cleaning the plates with acid or by burning is a considerable undertaking and, if the intervals between such a procedure can be lengthened, an occasional application of chlorine is definitely worthwhile.

Hatfield (37) of Decatur warns that the addition of chlorine to the air header may not at first appear to be of any value. He found that the action is somewhat delayed in its effect but that it works and has the advantage of being able to keep aeration tanks in operation while the plates are being treated.

Chlorine as Adjunct to Sludge Disposal

Foaming Control

Foaming is a problem at many sewage plants. Schlenz (38) mentions 8 possible causes of foaming, discusses each, and then gives 10 remedies. Many of these remedies consume a considerable amount of labor and are costly to execute. The use of chemicals such as lime or chlorine are the two chemical methods listed. Foaming often occurs when the pH of the digester contents is above 7.0. Lime is most generally tried first but when

this fails chlorine has often been found to be the answer to the problem. It has been particularly applicable where foaming has been rampant at Imhoff tanks.

In 1926, Enslow, at Austin, Texas (18), applied chlorine to the incoming crude sewage entering one of the Imhoff tanks. Even small amounts of chlorine reduced the tendency to foam and produced a more satisfactory tank effluent. Similar results have been reported at Lufkin, Texas (18) in 1928, and shortly thereafter at Breckenridge, Texas. Samson (39), in 1937, reported that for over 2 years prechlorination had been successful in controlling foaming at the Tonawanda, N. Y. plant.

Industrial wastes in the sewage often cause Imhoff tanks to foam. One of the earliest to report the use of prechlorination ahead of Imhoff tanks receiving sewage containing industrial waste was West, (40) at Stockton, California. The wastes were those from canneries and a cheese factory. Foaming occurred practically the year round but was always accentuated during the canning season. Prechlorination greatly reduced the foaming and the effluent became decidedly clearer.

Blohm (41), at the Westminster, Md. plant, had an unusual experience with distillery waste. In 1936, a year after the plant was placed in operation, the digester foamed. Lime with recirculation failed to stop foaming even when the pH of the digester contents was 7.2. The addition of 16 lb. of chlorine in the form of calcium hypochlorite stopped the foaming completely.

Chlorine for foaming control of Imhoff tanks is always added as prechlorination ahead of the tank. An application of 3 to 15 p.p.m. of chlorine usually suffices to greatly reduce the foaming and, in some instances, completely stop it.

Supernatant and Waste Activated Sludge Chlorination

The return of the supernatant liquor from the digester has often been a problem at many sewage plants, particularly when its return to the primary tank influent has resulted in an upset plant due to the overload created. At times, even secondary treatment units have been affected. Chlorination has often been the answer to the problem and it is expected to have widespread use in the future.

It is almost impossible to chlorinate the supernatant to a chlorine residual for it generally has a chlorine demand of 300 to 400 p.p.m. An application of 20 to 80 p.p.m. of chlorine per million gallons of supernatant usually suffices to take the load off the plant. The supernatant can be returned in the early morning when the chlorine demand of the raw sewage is at a minimum. The supernatant-raw sewage mixture is then chlorinated as it enters the primary settling basin. The supernatant can also be fed slowly but continuously throughout the day and in that way the prechlorination dose need be increased only slightly above normal.

The return of excess activated sludge to the primary settling tank at activated sludge plants is often a source of trouble. The activated sludge becomes septic and rises to the surface, retarding the normal settling and, hence, interfering with the activated sludge process. At the Willow Run bomber plant, Detroit, Michigan, Herda (42, 43) was confronted with an overloaded plant due to both the return of the digester supernatant liquor and waste activated sludge to the primary settling basins. He reported that chlorination of the waste activated sludge and the supernatant with 2 to 8 p.p.m. of chlorine, based on the waste activated sludge flow, resulted in great improvement in the set-

tling in the primary tanks and in the appearance of the plant effluent.

Sludge Thickening

The problem involved in returning the waste activated sludge to the primary units is quite often avoided by sending it to the digesters, or by drying it on vacuum filters. In either event, the excess return sludge first must be concentrated in tanks.

About 1930, Goudey and Bennett (44) eliminated the ill effects of returning waste activated sludge to the raw sewage by concentrating the sludge in separate tanks and then pumping it to the digesters. They applied chlorine to the upper strata of the liquid at the rate of about 25 lb. of chlorine per million gallons of sewage passing through the plant. In this way, they were able to avoid bulking and reduce the water content to 95 per cent.

Phoenix, Ariz., Topeka, Kans., Rockville Center, N. Y., and, more recently, the Tallman's Island plant of New York City have used chlorine for this purpose. It is usually used in the summer when the return sludge deteriorates most rapidly.

For satisfactory thickening, a chlorine residual must be maintained in the clear liquor above the settling or the compacting sludge in the tank. Addition of chlorine to the sludge as it enters the tank seems to give the best chlorine residual control. All who have tried this treatment agree that a 1 p.p.m. chlorine residual must be maintained in the clear liquid above the sludge.

Summary

Chlorine has many other minor uses in sewage treatment works operation which are not discussed in this paper. Regardless of the purpose for which chlorine is used—whether it be for effluent disinfection or as an aid to primary treatment, secondary treatment, or sludge disposal—the best advice concerning its use is to chlorinate intelligently, but not blindly.

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PAINTS AND PROTECTIVE COATINGS*

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The following notes and comments on paints and protective coatings are elementary in character. They are presented mostly as simple definitions and discussions, designed to give a general idea of the composition, properties, and relationship of the more common types of protective coatings. A better understanding of the fundamental nature of this class of materials will be of invaluable assistance in choosing the best type of coating for a given surface.

Primary Purpose of Protective Coatings

Primarily, protective coatings are applied to protect surfaces. The more common agents which attack surfaces and against which paint protection is desirable are:

1. Light—especially ultraviolet light
2. Water
3. Abrasives
4. Perspiration
5. Oil and grease
6. Chemical corrosives
7. High temperatures
8. Low temperatures
9. Temperature changes
10. Biological agents—bacteria, fungi, marine growths, etc.

Classification of Protective Coatings

The term protective coatings may be applied to a large and varied number of compounds. Protective coatings may be generally classified as follows:

1. Ordinary paints
2. Varnishes
   - Oil varnishes
   - Spirit varnishes
3. Enamels
4. Lacquers and synthetics
5. Calcimines
6. Aluminum paints
7. Bituminous types:
   - Asphalt bases
   - Coal tar bases

Ordinary Paints

Ordinary paints usually consist of a pigment which is thoroughly ground into a vehicle and conditioned for final use by the addition of a dryer and/or turpentine. Surface protection is accomplished by the pigment being bound to the surface by the vehicle through a process of chemical drying, with the formation of a tough, elastic film.

The vehicle is the most important ingredient of ordinary paint. Vehicles for paint use consist of drying oils. The three important drying oils in the general order of their importance are: (1) linseed oil, (2) Chinese wood oil (tung oil), and (3) soybean oil.

Drying Oils

Drying oils have the property, after processing, of undergoing chemical change by the combined process of absorbing oxygen (15 to 20 per cent) and undergoing an internal molecular rearrangement—a process known as polymerization—so that they dry out into a tough, elastic, insoluble film, the principal constituent of which is linoxyn. Linoxyn is the material that gives linoleum its name and well known wear properties.

Linseed Oil

Linseed oil is derived from flax seed. It is purchased as either raw or boiled oil. Raw oil is the refined oil and "dries" at a very slow rate. Where a

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particularly good job is desired and time can be allowed for the "drying," raw oil is often the more desirable to use.

Boiled oil is made by heating the oil in the presence of lead or manganese salts which partially satisfy the oxygen demand of the oil. Thus, boiled oils tend to dry in about 24 hours, which shortens the time for drying between coats.

Chinese Wood Oil

Chinese wood oil (tung oil) is the oil expressed from the nuts of the tung tree—a native of China. It can not be used raw but must be heated to a temperature of 400° to 550° F. in the presence of lead or manganese salts to properly prepare it for use. Its "drying" properties are similar to linseed oil. It is said to have considerable resistance to water penetration and is, therefore used somewhat for paints to be applied in damp places.

Soybean Oil

Soybean oil is the oil expressed from the soya bean. It closely resembles linseed oil. It is prepared for use by blowing a hot current of air, at 200° C., through the oil for several hours, and then filtering the oil.

Fish Oil

Fish oil is finding some use as a paint vehicle. It is the oil expressed from the menhaden of the Atlantic Ocean and the salmon and herring of the Pacific. After proper treatment it has but slight odor. When used in combination with linseed oil it is said to improve the water-proofing and heat-resisting properties of paint over that obtained by the use of straight linseed oil. It is, therefore, suitable for use on heated surfaces.

The "Drying" Process

It is important to underscore the fact that some protective coatings, such as spirit varnishes and most lacquers, dry by the simple process of mechanical evaporation and, accordingly, dry thoroughly in a short time. However, those protective coatings which contain drying oils, such as ordinary paints, oil varnishes, and enamels, "dry" by a process of chemical drying.

Chemical drying, even when accelerated by drying agents, takes time. The film is not dry when it feels dry to the touch. Time and the accessibility of air are necessary for the chemical reactions to take place. If this point is neglected and succeeding coats are applied too soon, the final result is likely to be faulty since the undercoat will creep, causing cracking, scaling, and other defects.

Paint Dryers

Paint driers have been developed in order to expedite paint drying without too seriously affecting the quality of the finished job. Dryers are known as oil driers and Japan driers.

Inorganic salts of lead (oxides-borates-acetates) and manganese (dioxide,, acetate, sulfate) are dissolved at high temperatures in linseed oil and are sold in the trade as oil driers. The Japan driers are made from organic salts of lead and manganese—the resinates and linoleates—dissolved in turpentine. In small amounts (less than 1 per cent) they act as catalizers, speeding up oxygen absorption.

Turpentine

Turpentine is universally used as a paint thinner and conditioner for final brush application. Turpentine is derived from the sap of the pine tree and from the steam distillation of wood chips from the Norway and Southern pine tree and from the Douglas fir tree.

Pure Gum Turpentine

Pure gum turpentine is gathered from the sap of pine trees in much the same manner as maple sap is gathered from maple trees, by a process called

"boxing." It is refined by steam distillation and leaves a residue of rosin.

Wood Turpentine

Wood turpentine is prepared by steam distilling wood chips from turpentine-bearing trees. The residue by-product is rosin. Pure gum and wood turpentine differ only slightly in composition or properties. The turpentines are frequently adulterated with mineral oils, and such adulteration is difficult to detect. Turpentine is strictly a diluent in paint and has little of the "drying" or film-forming properties of oil.

Paint Pigments

Paint pigments are derived from a very wide variety of sources. Some are manufactured, some mined. Most pigments are inorganic salts of the metals, such as those of lead, barium, and zinc. Some are of organic origin and are known as lakes. Any detailed discussion of this phase of paint composition is not compatible with the purpose of this paper.

Paint pigments are used for color effects. Color may be desirable for its decorative and aesthetic effects, or it may serve such utilitarian purposes as the easing of eye strain, with improved production and safety resulting. The DuPont Company, and others, have pioneered such uses of color. Color is also used for identification purposes, such as the designation of pipe and tank uses, as in a chemical plant. Pigments are sometimes used for protective and preservative purposes. The use of red lead for the protection of steel is an example of this.

The selection of the particular kinds of pigments to complete a given paint mixture involves a considerable knowledge of physical chemistry and the mechanical nature of the pigment particle. For example, a mixture of zinc and lead pigments is better for a white paint than either pigment alone. The zinc pigment alone is too hard and flinty, and lead pigments alone are too chalky. A combination strikes a happy medium. Where sulfur is present in the atmosphere, as around mining towns and sewage plants, lead pigments must be avoided since lead tends to form a black lead sulfide, and the paint darkens. To avoid this, titanium and zinc pigments are used. In some countries, such as France, the use of lead is prohibited due to the danger of producing lead poisoning or painter's colic.

Often cheap inert materials, called extenders, are added to the pigment. They are of value in improving the paint film by filling void spaces in the more granular pigments, much as fine sand is used to fill the voids in concrete and secure a more dense, impervious final mix.

One of the most important paint manufacturing processes is the grinding of the pigment into the vehicle used. This is done in burr-stone mills or with various types of roller mills. The purpose is not to reduce the pigment particle size but rather to introduce a pressure-shear action that separates the individual particles so that each particle is thoroughly enveloped by the vehicle.

The final paint mixture must have thixotropic properties. That is, paint must have the property of becoming fluid when worked by the brush. It must not solidify until after sufficient time has elapsed for the brush marks to flow out. On the other hand, it must solidify rapidly enough to prevent flow or sag. The degree to which paints have this thixotropic property and the care used in selecting the pigments determine the rate at which pigments tend to settle to the bottom of the container during storage periods.

All of this emphasizes the wisdom of avoiding cheap paints and of dealing with well-informed paint men who are familiar with paint characteristics and are, therefore, able to advise as to best application.

Aluminum Paints

Aluminum paints are in a class by themselves and when properly selected and applied are a valuable addition to the family of protective coatings. The aluminum powder, usually more-or-less flaky in character, is floated in either an oil varnish which dries chemically or clear lacquers which dry by evaporation.

The important ingredient of the mixture is the vehicle, since this determines its adaptation in use. Oil varnish vehicles are best for use where temperature is a factor, up to 1200° F. Lacquer vehicles are used where quick drying is desirable and high temperature is not a factor.

Due to over-emphasized advertising the average paint user thinks of aluminum paint as a cure-all for general application. This is unfortunate. Aluminum paints should be carefully selected for the particular use intended.

Bituminous Paints

Bituminous paints are generally used for the protection of metal surfaces, for high temperature work such as boiler fronts, and for the protection of concrete tanks, underground construction, and the like. The group generally consists of asphalt varnishes, asphalt enamels, and tar enamels. The latter are better suited for underwater protection.

Asphalt varnishes are solutions of solid bitumens, such as gilsonite, oil asphalts, and Bermudes asphalt, in volatile solvents and varnish. In other words, they are a mixture of resin varnish and asphalt varnish. Asphalt enamels like ordinary enamels may have pigments added for color effects.

Tar enamels are solutions of the residues obtained from the distillation of coal and wood tar. Benzene is the usual solvent for coal tar pitch. For wood tar pitch other solvents such as methyl alcohol and turpentine are required.

Special Paints

Paints are said to made more resistant to fire when additions of boric acid are made to them. When heated the boric acid tends to form a glasslike film that prevents access of air.

Ordinary linseed oil paints tend to quickly disintegrate when applied to concrete surfaces due to the presence thereon of calcium hydroxide—a strong alkali—which tends to saponify and so destroy the effectiveness of the vehicle as a binder.

One approach to this problem is called the Macnichol process. Here the concrete surface is first treated with zinc sulfate which converts the alkaline calcium hydroxide to calcium sulfate, thus neutralizing its effects. When soaps are applied the lime coating is converted to stearates or insoluble calcium soaps which become deposits in the voids of the concrete, thus promoting a water-proofing quality.

Sylvester alternates solutions of alum and soap, which cause deposits of insoluble aluminum hydroxide in the voids, with similar water-proofing properties.

Another method makes use of sodium silicate—water glass—which tends, partly, to form monocalcium silicate, and gelatinizes as silica in the voids of the concrete.

In short, all concrete surfaces must be sized by one method or another before paint can be successfully applied.

Calcimines

Calcimines, sometimes called distempers, are water paints, with water and an adhesive, such as casein or glue, as the vehcile. The pigments are usually whiting or gypsum and/or color bodies. Calcimines are manufactured by grinding the pigment and glue together, with a sterilizing agent such as boric acid or salicylic acid to prevent moulding. They offer some resistance to fire and do not wash off readily.

Varnishes

Varnishes are classified as oil varnishes and spirit varnishes. The oil varnishes are made by melting resins. Resins are of natural origin, found as exudations from ancient trees and usually mined in fossil form. Generally, resins are hard, brittle, transparent bodies, insoluble in alcohol.

Varnishes are manufactured by melting the resin, adding linseed oil, and thinning to proper consistency with turpentine. One of the resins employed is amber, which occurs in thin plates and nodules as the fossil remains of prehistoric conifers. Copal is similarly derived from ancient trees found in Africa. Kauri is a fossil resin from New Zealand and Demarara copal comes as fossil remains from South America. Oil varnishes dry, as does paint, by a process of chemical drying.

Spirit varnishes are solutions of resins in a volatile solvent such as alcohol, benzene, or turpentine. They dry quickly by evaporation. The most familiar member of this group is shellac. Shellac resin is an incrustration found usually on the *Ficus Religiosa* trees of India. It is formed from the sting of a tiny insect known as the *Coccus lacca*. The insect, feeding on the sap of the tree, manufacturers therefrom a resin which forms a shell about its body, thus creating the familiar shellac of commerce. It also produces a red dye of considerable value.

Other alcohol soluble resins used in spirit varnishes are (1) Mastic, derived from trees growing along the coast of the Mediterranian Sea; (2) Sandarac found on trees growing in Africa, and (3) the familiar rosin from pine trees.

Enamels

Enamels naturally come next in order, being oil varnishes to which have been added various pigments for the familiar and beautiful color effects produced. Like paint and varnish they dry by a chemical process and need a plentiful circulation of air.

Lacquers and Synthetics

Lacquers are a compartively new addition to the family of protective and decorative coatings. They were developed after the first world war and resulted from efforts to reduce the cost of manufacture and the cost and time required for the application of oil varnishes and enamels. Their development, in part, also grew out of the many new types of solvents which became available and the large stores of nitrocellulose then on hand.

Lacquers may be either clear or pigmented and can have excellent protective qualities. They are made by dissolving artificial resins, such as nitrocellulose, bakelite, vinyl resins, ethyl cellulose, chlorinated rubber-parlon, and many other synthetic types, in volatile solvents. Thus they differ from enamels by their ability to dry completely in a very short time, and in their use of the modern synthetic plastic-like resins in place of the natural resins. At present, although 90 per cent of all lacquers employ nitrocellulose, with or without pigment, many other combinations are available so that lacquers can be designed to meet a wide variety of special conditions.

Summary

It is to be remembered that this paper was intended to give only a brief outline of the simple fundamentals of the general family of protective coatings. Modern chemistry has extended the groups discussed herein into many variations and types, each with special properties for special purposes.

Today a coating for almost any specific use may be purchased from reliable sources. It is highly important to remember, therefore, that best results can only be obtained by wise selection and by a careful observance of the manufacturers directions concerning prime coats and the use of driers and thinners.

BARK FROM THE DAILY LOG

By W. W. Mathews

Superintendent, Gary (Ind.) Sanitary District

March 2—The sludge index is high today—452—but with no apparent effect on the treatment process; suspended solids and B.O.D. in the final effluent—12 and 3.6 p.p.m., respectively. All other plant factors are normal for the typical winter weather prevailing. Hosing out of the No. 1 aerator preparatory to cleaning diffuser tubes was not an attractive job in this cold weather.

March 5—Thawing temperatures encouraged a start on cleaning the diffuser tubes in No. 1 aerator. Secondary clarifier water levels were below the effluent troughs so that weirs and troughs could be cleaned. This practice is routine to remove slime. In the summer months algae grows luxuriantly on all vertical walls and baffles and in the effluent channels.

March 7—During the night the east agitator in No. 3 digester went out of service. Inspection showed that the shaft had pulled away from the upper coupling. We also discovered that a heavy scum layer had displaced the gas pipe at the east manhole. Some overtime was involved in getting the digester back on the line by late evening.

March 8—A beautiful day—in reverse! The early morning rain changed into a blizzard in the afternoon and evening. Then the sludge transfer pipe on No. 1 digester stopped up. This would happen on a Sunday! There was nothing to do but call out the men on the maintenance crew. They have long since ceased to wonder why breakdowns always occurred about quitting time or on Sundays!

March 9—This was a poor day for "public" relations. A complaint on basement flooding was received early in the morning and a lift station was found with the circuit breakers out. It had been inspected about one hour before, and at that time the pumps were operating as usual. This is one of those things that are bad for public relations. Regardless of how we explained the matter, the taxpayer still believed that someone had been careless about operating the pumps! Does that sound familiar?

March 10—A party of 33 students from Illinois Institute of Technology visited the plant this afternoon. Sometimes I wonder how much a student gets from an inspection trip of this kind. Engineering students are very attentive to descriptions on operation and design, but with only an hour or so to spend at a plant they can obtain, at best, only a "bird's eye view" of any plant visited. When several plants are visited in a day the impressions carried away are bound to be somewhat hazy. If time would permit, a small group of students spending a day at a type of plant in which they were particularly interested would obtain a really worthwhile picture of plant operation. This is just an idea and it may be practicable only when the plants inspected are conveniently located with reference to the college or university. Perhaps sewage works men should visit the same way!

March 11—This afternoon another lift station pump control circuit breaker was found "out." There seemed to be no apparent reason for this since there have been no electrical storms and the station is located several miles from the one which gave trouble on the 9th.

March 12—Another bad day! The lift station found out of service yesterday was down again when inspected this morning. In addition, the elec-

trician found the large pump circuit breaker "stuck" and the sump pump motor burned out! Gravel was found in the check valves of both pumps and the seat of one of the valves was out of place.

The electrician who rewound the sump pump motor suggested that the motor may have burned out because of the extreme humidity at the pump location. He suggested that we install a 100-watt lamp, with a reflector, adjacent to the motor and burn it continuously with the hope that the heat from the lamp would prevent the motor from burning out.

(Note:—This recommendation was followed and to date—Dec.—we have not had any trouble with the motor winding. Recently, on a routine inspection the operator reported that the light bulb was not burning and the circuit to the sump pump was apparently open. This light is on 220 volts because it was more convenient to wire in one at 220 than to run a 110-volt line down 30 to 35 ft. from the ground surface. Due to the previous trouble we had an electrician check the circuit and he could find nothing wrong with it. He said he had made no correction but that the power came back on. The sump pump has been operating without trouble since then. This is another puzzle for which we are still seeking a solution!)

March 16—The first real spring rains arrived today and the temperature shot up to 64° in the afternoon. Heavy showers at 4:00 and 9:00 P.M. necessitated pumping rates approximately 3 times the dry weather flow.

March 17—Spring showers may be wonderful for spring flowers but their effects on sewage treatment plants sometimes are not so beneficial. For example, yesterday's spring "showers" caused (1) flooding of the 48-in. Venturi meter pit; (2) deposition of large amounts of sand in the primary clarifier sludge hoppers, which had to be flushed out twice before raw sludge could be removed; and (3) clogging of the raw sludge header with sand from the primary clarifier hoppers.

March 18—Sometime during the night a section of lawn along the west side of the aeration basins settled so that several truck loads of dirt were required to level up the ground. A search was made for underground leaks but none were located. Luckily there were no pipes or conduits underground at this location or they certainly would have been sheared off.

No. 7 agitator broke down. A new grid spring was placed in the coupling and the agitator placed back in operation. The sludge hoppers in primary clarifiers were again clogged by sand.

Anyone but an operator reading the record of the last few days would undoubtedly get the idea that running a sewage treatment plant consisted mainly of repairs and trouble. These few days have been a little extreme as to troubles, mostly of a minor nature, but an operator has to be philosophic and, speaking in the vernacular, be able "to take it."

March 19—While all the maintenance trouble of the last three weeks has been occurring, the diffuser cleaning crew has cleaned the tubes in No. 1 aerator and partially cleaned those in No. 2 aerator.

March 21—No special maintenance work required today and everyone had time for routine work. The time available made it possible to survey plant operation for the month. So far this month sludge indices have ranged from 220 to 470. Effects of the high indices are not apparent. Solids and B.O.D. of final effluent are low and about where they should be for a normal index. Low B.O.D.'s in the final effluent indicate that nitrification is not causing the sludge to settle so lightly. Since the results are satisfactory we refuse to worry about the high sludge index but would be interested in knowing what is causing it.

March 23—Sludge removal from the drying beds is "business" here at Gary. Sludge is given away free for loading and hauling, which means we do not have to remove it from the drying beds. The saving effected is applied to our budget. Any saving indicated on the budget acts like a tonic. With the public removing the sludge, operation of drying beds consists of removing and replacing sludge boards, and draining sludge digesters. With this program, man-hours for sludge disposal are kept at a minimum. (Editor's Note: Permitting the public to remove sludge from drying beds is not practiced at most plants because of the resultant bed damage. At Gary, however, the plant site is practically pure sand and the sludge beds were constructed by scooping out enough top sand to provide berms. No underdrains are required and resanding the beds will never be a problem.)

March 25—Our chief operator discovered a break in a 6-in. line carrying final effluent to the rock garden. With about 600 lineal feet of this line consisting of straight pipe located in the open, the leak, of course, would occur under a sidewalk. It was uncovered and repaired, but the laborers had to watch their heads, for the depth of cover under the sidewalk was only 4½ feet.

March 26—Sludge customers having cleaned 13 sludge beds, each 44 ft. by 125 ft., end boards were replaced and banked with sand. Now we're ready for a refill.

March 28—After some springlike weather, snow storms returned yesterday and today. Low flows today indicated trouble somewhere in the collection system. A cable was found that had pulled out of the gate on one of the storm sewer regulators. As a result the diversion gate had closed diverting all the flow from a 108-in. sewer to the river. A block and tackle had to be used to open the gate and divert the flow back into the interceptor.

March 31—March ended cloudy and cool. This was a good month, with numerous maintenance problems. Although the sludge index ranged from a low of 187 to a high of 470, with an average of 320, treatment results were good. The final effluent averaged 5.9 p.p.m. suspended solids and 7.2 p.p.m. B.O.D.

April 3—The first of the April showers arrived today and from midnight until 8 A.M. we had to pump at a 40 m.g.d. rate. A ground in the 440-volt circuit necessitated shutting down the secondary treatment during the late afternoon and early evening, when repairs to the circuit were completed. In addition, a small lift station went out of service resulting in basements being flooded on the south side in afternoon. More good public relations in reverse! The heavy rains washed so much trash into the suction well that the pumps could not operate properly.

April 7—Signs of spring—the grounds keeper cleaning up and trying out the lawn mowers!

The diffuser tubes in No. 5 aerator are being replaced after cleaning. The No. 5 agitator was taken down and the high speed pinion was found to be broken and the drive shaft damaged beyond repair.

April 10—Here is a typical maintenance day—without breakdowns: north grit collector cleaned in morning, two comminutor pits cleaned, emergency overflow pipes on digesters flushed thoroughly, oil filter changed on No. 3 gas engine, grass seed sown on bare spot on lawn in front of building.

Just for the record, all of the equipment does not require continuous maintenance. There are 8 plant units that have been running continuously for over 7 years, being shut down only at short intervals because of other maintenance work. The only attention given them has been proper oiling and greasing at stated intervals. In the

main, manufacturers have done a very good job in developing sturdy and reliable equipment that stands up under continuous service.

At times the amount of grit we received at the plant is amazing. One test showed that for one hour grit removal was at the rate of 3.3 cu. yd. per million gallons. No, that is not a misprint; cubic yards is correct. At many plants the annual average removal of grit is from 1.0 to 2.5 cu. ft. per million gallons. At Gary our annual average for 1946 was 8.18 cu. ft. per million gallons.

The test noted above was taken when the man in charge of grit removal happened to remark that it looked as if the grit was coming in pretty fast. He was told to check the grit cars loaded during one hour and see how many he took out. The result was five 18-cu. ft. industrial cars, and the rate of pumpage at the time was approximately one million gallons per hour! This test did not necessarily reflect maximum removal. In contrast, there will be times during dry weather when less than one car of grit will be removed in 24 hours.

When such a slurry is being handled by comminutors, raw sewage pumps, and grit removal equipment, it is easy to understand why excessive wear results. The third set of impellers for the raw sewage pumps has been on order for over one year. The pump manufacturer has made a study of our conditions and has worked on the problem of increasing the life of the impellers by using various alloys.

April 11—Cleaned the sumps in the primary air filters. Found considerable dirt in the bottom of pans which is a visual demonstration that there is dust in the air about the plant. Cellulose secondary filters are used in series with the multipanel air filters.

April 14—The first lawn was cut today in front of the main building. One of the sewage lift stations was entered during the night by breaking down the door. No damage indicated, except to the door. There must be more profitable door-breaking possibilities than sewage lift stations!

April 17—Aerator No. 2 developed a crack in the floor. Apparently this was caused by upward water pressure. Since there are several well points and check valves in each aerator to relieve the floor from uplift pressure, this came as quite a surprise, particularly since the well points were functioning at the time and there were several other aerators also drained down. These were immediately filled with several feet of water to prevent any further damage.

April 18—A new thermal protection unit was installed on No. 5 engine. We found that No. 5 was not getting the proper thermal protection when the jacket water went to a temperature of 175° F., and that the engine was not shut down by the thermostatic control. Engines No. 4 and 5 are protected for 172°, while No. 1, 2 and 3 are set for about 10° lower. These settings are by the manufacturers of the respective groups of engines, which accounts for the difference in the settings. The manufacturers recommend operating temperatures lower than those ordinarily encountered in operating automobiles. No. 4 and 5 run at about 140° F. and No. 1, 2, and 3 at about 145°F.

April 22—Summer is in the offing. Screens were placed on the main building today and the heat was cut off. Maintenance is very much routine now, draining sludge from digesters, cutting lawns, flushing drain lines, etc.

April 27—The return sludge line from No. 6 secondary clarifier stopped up, and when discovered the tank was giving a very good imitation of bulking. The stoppage must have occurred some time during the night for the sludge blanket level was at the water surface in the tank.

April 30—The month ended very quietly with a warm summery day.

The sludge index is still up but, as before, has had no effect on the treatment results, which are satisfactory. Purchased power consumption was down about 21,000 kw.-hr. as a result of higher rates of gas production. Aeration was carried 100 per cent on gas, and raw sewage pumping 94.5 per cent. With a reduction of cost over the previous month and the plant functioning properly, what more could an operator ask for? Nothing! But we're keeping our fingers crossed—and our eyes open!

INTERESTING EXTRACTS FROM OPERATION REPORTS

"The best that a man ever did shouldn't be his yardstick for the rest of his life."

—*Louis F. Swift*

Attention operators! It will be appreciated if copies of all annual reports of both large and small plants are sent to the Federation office for abstracting in this section of the Journal. Carbon copies of typewritten reports will be promptly returned on request. Please direct annual reports to: Federation of Sewage Works Associations, Room 325, Illinois Bldg., Champaign, Ill.

Sixth Operation Report of the Sewage Treatment and Garbage Disposal Plant, Marion, Ind. for the Year 1946 *

By David Backmeyer, *Superintendent*

Type of Plant

The Marion plant is of the separate-sludge digestion, diffused-air activated sludge type. Municipal garbage is received at the plant, ground, and pumped directly to the digesters.

Change in Garbage Payment Policy

During the past years it has been the policy of the Sanitation Department to pay to the City General Fund a fee of $1.00 for each ton of garbage delivered to the sewage treatment plant. This transfer of funds was discontinued on September 30. A review of the operation data on hand indicated that from a financial standpoint this transfer of funds was no longer warranted. This change of policy was due primarily to the increase in maintenance costs of the garbage-grinding and sludge digestion facilities.

Gas Recovery

The recovery of sewage gas from the digestion of the sewage and garbage solids continued to provide the fuel requirements for all of the heat and 74.9 per cent of the total plant power load. The total cubic feet of sewage gas produced was practically equal to that of 1945, and the value of the gas utilized was estimated at $11,077.50.

Sale of Liquid Sludge

Total receipts from the sale of the liquid byproduct sewage sludge was the greatest for any year to date, although the increase in cost of operation of this department resulted in a net operation loss of about $3,500 for the year.

* For previous extracts see This Journal: **18**, 2, 317 (March, 1946); **16**, 5, 1000 (Sept., 1944); and **14**, 3, 722 (May, 1942).

Excerpts from the Daily Diary

As per the suggestion of the Hartford Insurance inspector, both the 50 p.s.i. and 250 p.s.i. air storage tanks are raised ½ in. from concrete bases to allow air passage under bottoms of tanks and eliminate any possibility of moisture accumulation at tank bottom.

Quarry pond adjacent to plant in good condition for skaters. Mr. Chambers provides music for the evening crowd by playing recordings over amplification system installed on roof ledge of digestion tank.

Limit torque control on sluice gate is not set properly. This is one of very few pieces of equipment that we do not have operation drawings for in our equipment files.

No. 3 gas engine, 75 hp., driving blower, is shut down for regular inspection after run of 6,614 hours. All rod bearings in this engine were in bad condition and had to be replaced. Bearing shells were cut to exact size at machine shop, but the fitting job done in mounting the shells was very poor. Some of the trouble may also be attributed to poor quality lead-base bearing babbitt sold during the war when tin was not available. The bond of the babbitt to the brass bushing was bad.

Check on temperature of bottom sludge in primary digester indicated circulation was needed. Recirculating sludge in this tank increased bottom temperature from 58° to 84° F.

Electricians complete rewiring job at plant which involved changing and replacing practically all circuits which were originally installed with lead sheath cable. Overhead fully exposed conduits would have been a much better original installation.

Two mercury vapor lamps installed in compressor building where vibrations cause early failure of incandescent bulbs.

TABLE I.—Summary of 1946 Operating Data, Marion, Ind.

Item	Average
Total rainfall (in.)	29.46
Estimated tributary population	30,000
Equivalent population (from B.O.D.)	39,100
Sewage flow (m.g.d.)	4.59
Suspended solids (not including garbage solids):	
Raw (p.p.m.)	187
Primary tank effluent (p.p.m.)	139
Final effluent (p.p.m.)	13
Overall removal (%)	93.0
B.O.D.:	
Raw (p.p.m.)	174
Primary tank effluent (p.p.m.)	152
Final effluent (p.p.m.)	13
Overall removal (%)	92.8
Activated sludge:	
Detention in aerators (hr.)	4.04
Sludge index (Mohlman)	91
Suspended solids mixed liquor (p.p.m.)	2,669
Raw sludge:	
Thousand gal. pumped	728.2
Total solids (%)	4.36
Volatile solids (%)	66.8
Solids in supernatent (1,000 lb.)	61.68
Digested sludge:	
Total solids (%)	3.12
Volatile solids (%)	53.4
Dry solids removed (tons per month)	95
Garbage disposal:	
Green garbage to grinders (tons)	1,300.7
Ground garbage to digesters (1,000 gal.)	656.33
Total solids (%)	6.82
Volatile solids (%)	90.7
Digester gas production:	
Total gas produced (1,000 cu. ft.)	23,566
Cu. ft. gas per capita per day	2.42
Cu. ft. gas per lb. volatile	10.12
Percentage of total power furnished by digester gas	74.9
Treatment costs ($):	
Cost per ton dry solids removed	3.61
Revenue from sludge sales	1,703.85
Net cost per ton dry solids removed	2.11
Gas and power cost per 1,000 lb. B.O.D. removed	1.79
Labor cost per 1,000 lb. B.O.D. removed	9.57
Cost per million gal. sewage treated*	20.28
Cost per 1,000 lb. B.O.D. removed*	15.18
Cost per capitia*	1.26

* Does not include new equipment bought or financial charge on plant investment.

New drag shoes being put on sludge collector in No. 2 primary settling tank. Analysis of sludge fertilizer as reported by Purdue University is: total N—2.66 per cent, total phosphate —3.7 per cent, and potash—none.

Piping changed in basement of service building so that sludge meter can be checked by pumping into truck tank and weighing contents of load.

With two blowers operating against a head of 8.3 p.s.i. on the discharge about 70 hp. The gas engine-driven unit was 80 amp., or an equivalent of about 70 hp. The gas engine driven blower operating with the electric driven unit was therefore running at about 93 per cent of its rated 75 hp. capacity.

Due to marked increase in building replacement costs coverage for insurance on plant buildings is increased.

Aeration tank No. 1 is shut down to give tubes much needed cleaning before canning plant waste arrives. Chromic acid, made up according to Chicago Pump Co. specifications, used for cleaning solution.

Seven teen-age girls are having grand time using our effluent creek for wading pond. When told that the source of the water was the outlet of the sewage treatment plant the party disbanded almost immediately.

Brass tubes in heat exchanger are 24 months old today. Life span of two previous sets of iron tubes was 30 months and 22 months.

Machined mandrel made up to give pattern of crankshaft for fitting bearing bushings in work shop. This will save the operator doing the work a lot of unnecessary walking.

Arrangements being made to draw raw sludge through sight-valve to sludge well in effort to get higher solids concentration in the sludge.

Operating data for the year are given in Table I.

1946 Report of the Sewage Treatment Plant, Dayton, Ohio

By Lloyd C. Huffman, *Superintendent*

The sewage treatment plant operated 365 days with but one stoppage. This was caused by an insulation failure on one phase of the high tension line just before it entered the pot head on the underground conduit leading to the transformer vault.

The total sewage flow for the year was 12,800 million gal., with approximately 266 million gal. of raw sewage bypassed during January when new mechanically-cleaned bar screens were installed in the wet wells at the Broadway pumping station.

Description of Sewage Treatment Units

Skimming Detritus Tank

Two units—40 ft. dia., 15½-ft. wall depth; capacity 37,000 cu. ft.; detention—15 min. @ 26 m.g.d.

Grit Channels

Two mechanically cleaned units.

Fine Screens

Two Dorr self-cleaning screens, 4 ft. by 6 ft. with ⅛-in. by 2-in. slots; two bucket-type elevators; hydraulic screenings press and pump, pressure capacity 100 tons.

Imhoff Tanks

Six units, horizontal flow; length—88 ft., width—73¾ ft.; sedimentation compartment—88 ft. by 9⅓ ft. with 13-ft. total water depth; sedimentation period—2.2 hours, vol.—1.24 cu. ft. per cap.; sludge compartment: vol.—429,000 cu. ft.; gas vent area—2.3 per cent total tank area; gas collected from all tanks.

TABLE II.—Summary of 1946 Operating Data at Dayton, Ohio

Item	Average
Rainfall (in.)	30.46
River flow (c.f.s.):	
Max. month, ave.	3,713
Min. month, ave.	260
Ave. for all months	1,588
Tributary population, equivalent	358,520
Sewage flow:	
Total (m.g.)	12,820
Ave. daily (m.g.d.)	35.17
Ave. max. hourly (m.g.)	1.86
Bar racks and detritus tanks (lb. dry solids removed):	
Detritus skimmings	34,500
Detritus grit	6,600
Detritus screens	568,000
Broadway station detritus racks	448,000
Suspended solids:	
Raw (p.p.m.)	259
Settled (p.p.m.)	100
Filter effluent (p.p.m.)	80
Final (p.p.m.)	36
Per cent removal	86.5
B.O.D. (5-Day):	
Raw (p.p.m.)	208
Settled (p.p.m.)	119
Filter effluent (p.p.m.)	43
Final effluent (p.p.m.)	27
Per cent reduction	86.8
Filter loadings:	
M.g. per day	35.12
M.g. per acre-ft. per day	3.64
Pounds B.O.D. per acre per day	3,757
Pounds B.O.D. per acre-ft. per day	474
Pounds B.O.D. per 1,000 cu. ft. filter media	10.86
Material removed from Imhoff tanks (pounds dry solids per month):	
To digesters—12 mo.	644,000
To lagoon—11 mo.	91,000
To drying beds—9 mo.	207,000
To river—2 mo.	103,000
Material removed from digestion tanks (pounds dry solids per mo.):	
To drying beds—4 mo.	86,000
To lagoon—11 mo.	248,000
To river—4 mo.	214,000
Elutriated—6 mo.	142,000
Gas produced (1,000 cu. ft.):	
Digester	30,200
Imhoff tank	43,100
Total	73,300
Fertilizer operations:	
Operation costs ($):	4,031.32
Personnel	2,690.94
Equip., supplies	1,340.38
Total sales ($):	10,441.91
Retail	744.15
Wholesale	9,697.76
Profit ($)	6,410.59
Farm operations ($):	
Income	8,684.73
Expenditures	6,914.98
Profit	1,769.75
Sewage plant costs ($):	
Administration	7,760.37
Operation	82,315.98
Maintenance	14,127.27
Total	104,302.62
Net sewage plant cost ($)	97,793.03
Net sewage plant cost per m.g. sewage treated ($)	7.63

Trickling Filters

Twenty units, each 165 ft. dia., 7½ ft. slag depth; total area—9.81 acres; total vol.—3,200,000 cu. ft.; 20 automatic siphons and rotary distributors.

Final Settling Tanks

Six units, 80 ft. dia., 9 ft. sidewall depth; capacity—45,300 cu. ft.; mechanical sludge collection.

Concentration Tank

One unit, 10 ft. by 10 ft. by 75 ft.

Sludge Digesters

Six units; 50 ft. dia., 22-ft. sidewall depth; floating covers.

Sludge Beds

Eleven covered beds, total area 105,000 sq. ft.; seven open beds, total area 71,6000 sq. ft.

Garbage Grinder

Jeffery.

Fertilizer Equipment

Herreshoff multiple hearth furnace, 25 ton dry solids per 24 hr. capacity, and appurtenances.

Operation Data

A summary of operation data for the year is given in Table II.

TWO SOUTH TEXAS SEWER ACCIDENTS TAKE FOUR LIVES

By Otto Paganini

Sanitary Engineer, Hidalgo County Health Unit, Edinburg, Texas

Within the short space of 25 days, sewage works accidents claimed the lives of four South Texas sewage works men. Press reports labeled the deaths accidental, but in every respect these deaths were preventable. Even a minimum of caution and safety-mindedness would have made them impossible.

First Accident

In the first "accident," a sewage works superintendent and his assistant lost their lives in a sewage lift station wet well, in an attempt to repair defective pump control floats.

The wet well is of conventional construction—5 ft. in diameter and 14 ft. deep. The vertical, submerged, electrically driven sewage pumps and the float controls are supported by a solid metal plate which constitutes the top of the wet well. Access to the wet well is through a 14-in. by 20-in. manhole opening between the float controls. The 12-in. trunk inlet sewer enters the wet well 5 ft. below the wet well top and directly beneath the entrance manhole. Ventilation of the wet well is supposedly provided by a 4-in. diameter stack which extends from the top of the wet well and vents through the lift station wall, about 4 to 5 ft. above the ground. A brick wall, 6 ft. high, surrounds and protects the pump motors and float controls from the weather. Originally, a circular split-hatch type cover on top of the wall provided the only access to the pump motors and the wet well.

The lift station is part of a new sewerage system which had been in service for only about three months. The 12-in. trunk sewer discharging at the lift station is about 2 miles long.

Upon completion of the lift station the superintendent and the writer had discussed the difficulty of servicing the pumps and motors, since the only entrance to the pump room was through the top opening. As a result of the discussion, a 23½-in. by 43½-in. door opening was cut out on the west side of the station.

Previous Exposure

Three weeks prior to the accident the superintendent had entered the wet well and installed a 2-in. by 4-in. wood brace between the guide tubes of the float rods. This was done to prevent the floats from hanging on the wall of the wet well and causing the pumps to operate continuously, which had previously happened. The superintendent had encountered no difficulty while doing this work.

On the day of the fatalities the superintendent and his assistant went to the lift station about 10:30 A.M. to repair the pump control floats, which were leaking. Previously, the superintendent had informed his wife to send someone after him if he did not return home for lunch, since the work he was going to do was hazardous.

At the lift station the superintendent apparently tried to remove the float valve and guide rod mechanism from the wet well by lifting them out from the top. The 2-in by 4-in. wood bracer between the float rod guide tubes evidently prevented this. It is assumed that the superintendent then removed the manhole cover, placed a ladder in the wet well, and proceeded to descend into the wet well to remove the wood brace. In all probability he was overcome and either slumped on the ladder or fell to the bottom of the wet well. The body showed several bruises. In-

formation as to whether the electric power was off was not available; however, the possibility of electrocution is discounted. Meanwhile, the assistant, seeing the superintendent was in difficulty, apparently also descended into the wet well and was similarly overcome.

When the superintendent did not return home for lunch, his wife called the city hall. The city secretary accompanied by the mayor, immediately went to the lift station. Although no one was observed, there was evidence that the men had been working there and had probably left for home. A check soon revealed that they had not returned home. The city secretary and the mayor returned again to the lift station where, about 2 P.M., they discovered the bodies by probing the wet well with a long pole. The Fire Department was called and removed the bodies with grappling hooks. A verdict of "accidental suffocation with subsequent drowning" was given as the cause of death by the investigating justice-of-the-peace.

Inspection of Lift Station

The superintendent and the writer had inspected the lift station wet well just a few days prior to the accident and had discussed the manner in which the floats could be removed and repaired. The superintendent was aware of the hazards involved in entering the wet well and was cautioned not to enter the wet well without providing adequate prior ventilation or without observing the proper precautions. He was also advised that the float rod guide tube and float rod mechanism could be removed without entering the wet well.

Second Accident

In the second "accident," a drainage well was being used to dispose of the sewage and industrial wastes from a local citrus-packing shed by discharging the wastes into a subterranean gravel stratum. The cistern of this drainage well (see Figure 1) is 10 ft. in diameter and 12 ft. in depth. At the center of the cistern floor there is a 4-in. casing discharging to a subterranean gravel stratum 50 ft. below the ground. The cistern is covered with a concrete roof having a 24-in. manhole in the center for entry purposes. Adjacent to the drainage cistern is located another cistern which is 8 ft. in diameter and 12 ft. in depth, and which is used as a settling basin to trap organic solids, and thus prevent plugging of the drainage well.

Difficulty was being encountered with the drainage well in that it would not carry off the waste water fast enough. On the date of the accident attempts were being made to unplug this well. The cistern was emptied from the ground by the use of hand lines and buckets. After the cistern was empty, a man was instructed to enter the cistern and pour Sani-Flush into the drain well. He was cautioned to come out of the cistern immediately after emptying the cans. The man did not come out as instructed, and shortly collapsed. A second man volunteered to go into the cistern after the first one. A line was tied around him and he was given a second line to tie around the body of the first man.

Second Man Overcome

Information is vague concerning what happened when the second man reached the bottom of the cistern. Apparently the upper end of the line to be used for removing the first man was accidentally dropped into the cistern from above. The second man then took the line attached to his own body and tied it around the body of the first man. He then lost consciousness. The first man was removed as a third man went into the cistern without any protection other than holding his breath. This third man was able to tie a rope around the second man but experienced respiratory difficulty while

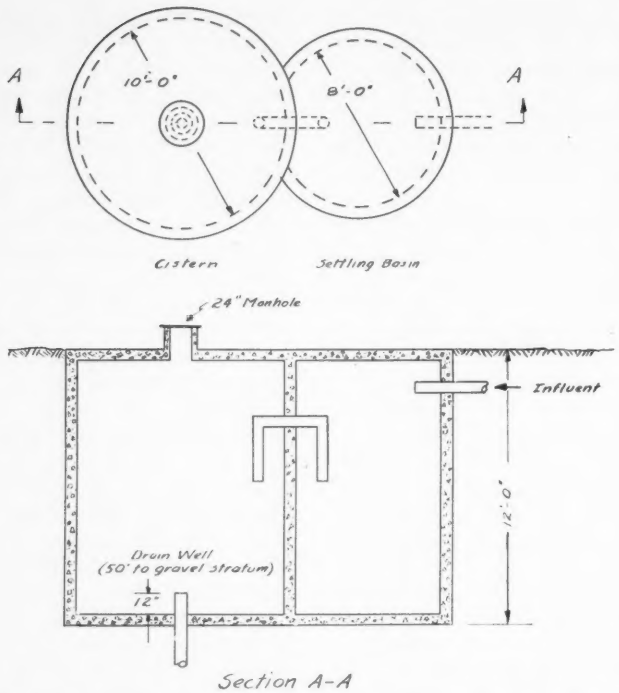

FIGURE 1.—Drainage-well cistern of citrus-packing company.

climbing out of the tank and collapsed upon reaching the top of the cistern. The first and third men were revived and taken to the hospital, but nothing could be done for the second man. The first man lived until the next morning, and the third one recovered.

The cause of death in both accidents can only be surmised. If there was a high percentage of hydrogen sulfide present or a deficiency of oxygen, either one of these conditions could have resulted in the death of these men. The lack of sufficient oxygen in the atmosphere may have been the primary cause of death, although a fairly high concentration of hydrogen sulfide would have materially contributed to the asphyxiations.

Three weeks after the first accident, tests were made of the atmosphere in the sewage lift station wet well. At that time the H_2S concentration was 200 p.p.m., the O_2 content 20 per cent, and the CO_2 content 0.3 per cent. There was no explosive gas present. No tests were made of the atmosphere in the drainage well cistern of the citrus-packing company.

The most significant fact concerning these regrettable accidents is that they were preventable. A proper appreciation of the hazards involved and an intelligent use of available protective devices would have saved four lives. The safety precautions which must be observed when working in potentially toxic or oxygen deficient atmospheres should be as familiar to every sewage works man as his name. These are clearly and understandably discussed in the Federation's Manual of Practice No. 1—"Occupational Hazards in the Operation of Sewage Works." Briefly summarized, these safe practices are as follows:

1. Both supervisory and labor sewage works personnel, together with local firemen and policemen, should be thoroughly acquainted with the hazards involved when working in and about sewage works.

2. No one should enter a confined or enclosed sewage works area unprotected, unless the area has been proven safe for entry.

3. All sewage works pump pits, wet wells, manholes, or other enclosed spaces should be provided with means for positive ventilation and should not be entered until tested for toxic and explosive gases and oxygen deficiency. Persons testing enclosed spaces should wear approved (U. S. Bureau of Mines) protective equipment. Test equipment, such as H_2S and CO detectors, oxygen deficiency indicators, explosion meters, etc., should be of an approved type.

4. Whenever an individual must enter a confined or dangerous area, a safety belt with attached line should be worn, with one or two men attending the individual so that he can be removed from the area if difficulty is encountered. The surface end of the life line should be secured to prevent its loss.

5. When extended work is required in dangerous closed spaces, positive ventilation should be provided by means of a nonsparking blower having sufficient capacity to effect a complete change of air every 2 minutes. The intake of the blower should be located so that only fresh, clean, safe air is conveyed to the working area.

6. Approved (U. S. Bureau of Mines) respiratory-protective equipment, such as self-contained oxygen masks and hose masks, should be used when entry must be made into areas which have not been proven safe, or which have been proven unsafe. Removal of toxic gases or oxygen deficiency by natural draft or forced ventilation can frequently convert unsafe areas into safe working areas. This practice is preferable to the wearing of any type respiratory-protective equipment. Because self-contained oxygen breathing masks are complicated for general use and require special training for safe use, the hose mask is the preferable respiratory protector for workers in sewage works areas containing dangerous atmospheres. Canister masks of any type should not be worn in sewers or digestion tanks because of the possibility of oxygen deficiency and, in the case of sewers, of petroleum vapors being present.

TIPS AND QUIPS

Something New in Sewage Works Revenue

Arthur Morrill, for many years with the Department of Water Supply of Detroit, and U.S.P.H.S. representative in China during the war years, has returned to China where he will be working with the Ministry of Health in his capacity as consulting sanitary engineer for the World Health Organization of the United Nations. While waiting a few days at the fabled Cathay Hotel in Shanghai before resuming his journey to Nanking, he found time to write us about the latest in sewage works revenue schemes, Chinese style. His report follows " . . . Enclosed is a clipping from the Shanghai Evening Post tonight, a new idea for financing sewer systems. The movie film distributors don't seem to like it but it appears like a swell scheme to me. This Chungking sewer system is the most successful thing I have been connected with so far. The city borrowed the money from the government banks and I have been wondering how they were going to pay it back. This

is the first I have heard of the special tax on movie tickets. Probably only a small fraction of the total cost is coming from that source."

The clipping referred to concerns a proposed 20 per cent "winter relief surcharge" on the gross receipts of Shanghia theaters. In discussing the proposed tax, the film distributors revealed they already have experienced a series of similar surcharges in Chungking, Kunming, and Changtu, where authorities placed a profit-cutting surcharge on admission tickets for such "projects" as "the building of a sewerage system." The "surcharge" is to be in addition to the existing 25 per cent amusement tax and 5 per cent stamp tax.

If the films being shown in Shanghai bear any resemblance to those making the rounds of the local movie mansions, one can understand where the sensitive Chinese got the idea for a sewage works tax. It should catch on even in this land of obtuse perceptions, whose politicians, however, are not far behind the matter-of-fact Chinese in spotting even a slight excuse for a new tax. Would such a tax in this country resolve the Johnston Office into a pollution control agency?

Incidentally, in Shanghai, theater admissions now range from 15,000 to 35,000 Chinese dollars, a fancy price to be sure, but not out of line with other costs, as reported by Arthur Morrill: " . . . This newspaper (Shanghai Evening Post) cost 5,000 Chinese dollars, which is about five or ten U. S. cents, depending on what exchange rate you have to use. Since I left in May they have introduced $10,000 bills, but it takes five or ten of them to buy a meal, so they are getting to be too small already."

Let's count our lucky stars, and hope against hope that the day never comes when $500,000, or some other such ruinous figure, will be required to keep the SEWAGE WORKS JOURNAL on your desk!

Made-to-Order Rain Storms

Activated sludge plant operators, who during the dry, hot, summer months anxiously scan the skies for signs of a refreshing rain, may be in line for some scientific help in the future. A new method for producing rain, by which ordinary water dispersed in small quantities into actively-growing cumulus clouds initiates a "chain reaction" rainfall from such clouds, was disclosed by Dr. Irving Langmuir, associate director of the General Electric Company's Research Laboratory, at a recent meeting of the National Academy of Sciences.

Cumulus clouds having the characteristics necessary for the new rain-making method to be effective are found frequently in the summer in the northwest part of the United States and all year round over the South and the Pacific Coast.

Now that rain making has possibilities of becoming an order-filling proposition, it probably won't be long until the harried sewage works man can call the municipal rain-maker and order a rain of the proper size when the days turn hot and dry, and the activated sludge index starts upward. Such a prospect is intriguing!

A note of pessimism creeps into this dream, though. Who is to decide when it shall rain? And how much? And where? Already the Salt Lake City Chamber of Commerce has threatened federal court action against its Reno, Nev., counterpart for "milking" clouds of snow as they pass over Reno on their way to Salt Lake City!

Iowa Sewage Works Association Starts Newsletter

An information-packed news letter joins a fast-growing membership roster as concrete evidence of the increased activity of the Iowa Sewage Works Association. The 4-page (legal size) mimeographed first edition presented more than a dozen items of interest to

Iowa sewage works men. Chief of these was an account of the 1947 annual meeting at Cedar Rapids, and a report of the proposed training program for sewage works operators.

The proposed training program is unique in several particulars. Designed to take training information to the operators, the program is being developed as a home study training course, and will be administered by the Engineering Extension Service of Iowa State College.

Sponsored by the Iowa Sewage Works Association, the Sanitary Engineering Division of the Iowa State Health Department, and the Engineering Extension Service of Iowa State College, the program is to consist of five courses of twelve lessons each. In general, the courses are to be progressively arranged, the study material starting with the fundamental and basic features of sewage treatment and progressing through the more advanced and detailed aspects of the subject. The Engineering Extension Service of Iowa State College will send out the lesson material and will review the work of each student.

Upon satisfactory completion of each course, the work will be graded and a certificate will be issued. Cost of the home study course will be $6 for each course of 12 lessons, with the entire series of five courses costing $30.

The study courses have been prepared by Prof. W. E. Galligan of Iowa State College. In addition to the five courses now planned, courses dealing with Public Relations and First Aid will also be offered.

A prospectus giving a general outline of the courses of study offered may be obtained by writing the Engineering Extension Service, Iowa State College, Ames, Iowa. Information is not now available as to whether sewage works men not residents of Iowa may enroll for these home study courses.

President Charlie Alexander and the members of the Iowa Association are to be commended for the excellent work the association is doing for all Iowa sewage works men.

Caution Advised in Use of Self-Contained Breathing Apparatus

Ever alert to new developments in sewage works safety practices, the Federation's subcommittee on "Occupational Hazards," through its chairman, LeRoy Van Kleeck, has directed attention to the recent Bureau of Mines circular on the approval of the newly developed self-contained breathing apparatus (I.C. 7413, U. S. Bureau of Mines: "Approval of Newly Developed Self-Contained Breathing Apparatus, Instructions in its Care and Use, and Training Procedure").

Concerning the applicability of these newly developed breathing devices to the general sewage works field, Chairman Van Kleeck states: "It is my feeling that our original recommendation to use a hose mask is the best and still stands for most cases. Operators planning to use the newly developed breathing apparatus should be familiar with the information in the Bureau of Mines circular (I.C. 7413), particularly with respect to the bureau's recommendation that basic training should be required in the handling of all types of self-contained breathing apparatus. It is of interest that on the last page of this circular it is stated that mine rescue certificates will not be issued for training done with auxiliary types of breathing apparatus only, such as the four new types described in the circular."

Self-contained breathing apparatus can be used with reasonable safety in an irrespirable atmosphere only by those trained in the care, use, and limitations of this equipment. Those without such training should continue the use of hose masks!

Several copies of the Bureau of Mines Information Circular 7413 are

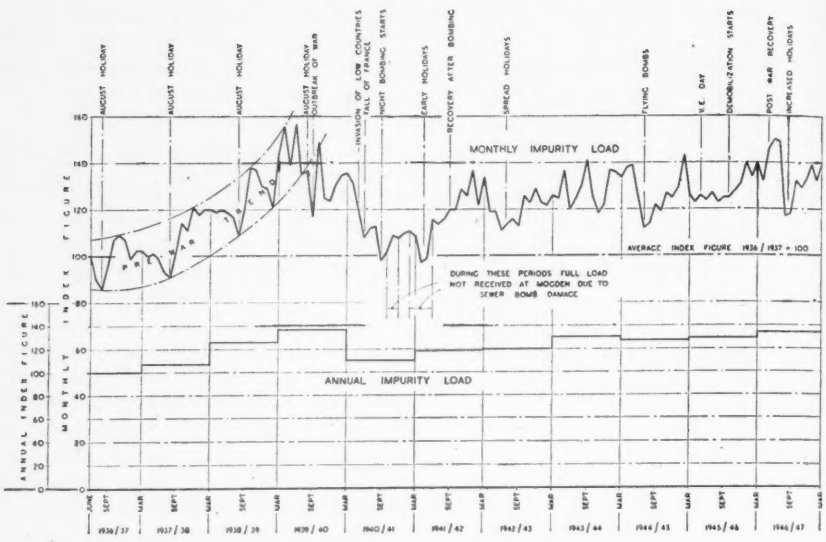

FIGURE 1.—Diagram of impurity load at the Mogden Purification Works, West Middlesex Main Drainage District (England).

available at Federation headquarters and as long as the supply lasts will be sent to members free of charge upon request. The circular may also be obtained directly from the Bureau of Mines, Department of the Interior.

Sewage Strength Reflects Community Activity

Sewage works men have long known of the accuracy with which the quantity and character of sewage flow reflect the fluctuating trends of metropolitan and urban living. Of course, the advent of the melon season is obvious even to the neophytes of a profession whose veterans claim the ability to interpret the social and recreational life of their communities and even predict the hills and hollows of next year's population curve.

This inherent ability of sewage to mirror the life processes of those whose byproduct it is, a fact but vaguely understood by the layman, has never been more graphically demonstrated than by the Impurity Load Diagram prepared for the Mogden plant of the West Middlesex Main Drainage District, England, and presented in the paper "Operating Experiences—West Middlesex Main Drainage," by C. B. Townend and W. T. Lockett at the annual summer conference of the Institute of Sewage Purification last July at Glasgow, Scotland.

The diagram, Figure 1, provides a remarkably faithful indication of the activities of the contributing district during the period covered and of the impact of every major event on these activities.

Such a record was made possible only because the entire impurity load has been tributary to Modgen during periods of rain as well as in dry weather, none being discharged into the rivers by storm overflows. The total impurity load is shown as an index figure which incorporates the results of the following tests: (1) oxygen absorbed in 4 hours, (2) the albuminoid nitrogen, and (3) the 5-day B.O.D., calculated in relation to a basis of 100 for

the year 1936–37. The chart tells its own story and needs no comment.

Sewage analyses at the Modgen plant also have clearly illustrated the effect of England's food shortage and rationing on sewage strength. In prewar days the B.O.D. load of domestic sewage amounted to about 0.155 lb. per person per day. In recent years, however, this has decreased to no more than 0.120 lb. per person per day, or even less. This compares with the American standard figure of 0.167 lb. per capita.

Dr. Karl Imhoff, in an unpublished report, indicated that due to the deteriorating German war diets the gas yield at German sewage plants dropped from 30 to 40 per cent during the war.

These facts are in stark contrast to our abundant diets, and bring back memories of our wartime complaints about rationing and limited food scarcities. Now that food of all types is plentiful (?) once more, one wonders if the minor shortages of the war years limited our national diet enough to be reflected in day-by-day analyses of sewage strength. If the data were available, an analysis of the changes in the American diet during the past three decades would be illuminating. Perhaps some inquisitive and truth-loving member of the profession will feel constrained to search his records and chart for us his version of the rise and fall of America's food consumption!

Tips for Longer Instrument Life

The average sewage works man probably knows less about metering and recording instruments than about any other type of sewage works equipment. Nearly all, however, have experienced the delay incident to the repair or replacements of such devices and have looked more than once at the amounts of the ensuing bills. Due to the delicacy and complexity of these instruments, local repair, or even adjustment in some cases, is inadvisable.

The suggestions for increasing instrument life and efficiency carried in the Nov.-Dec. 1947, issue of the J. W. Murphy's *Metering Messages,* are worthy of study and application whenever possible. A check-list of these suggestions follows:

Correct Location

Incorrect location and installation of industrial instruments causes more trouble and inaccuracy than fault or failure of the instruments themselves. Don't neglect to install instruments where they can be properly serviced and protected. This is almost as important as the basic requirement of being sure the measuring unit is installed so it measures the temperature, pressure, etc. desired.

Assign Responsibility

Preferably make all instruments in the plant the responsibility of one man or group of men for care and maintenance. Do not leave responsibility for this to the men operating the equipment on which the instruments are installed. Such practice often results in complete lack of maintenance until instruments break down, or in harmful tampering by men who are not familiar with instrument operation.

Prevent Vibration

Prolonged vibration and shock resulting from careless handling are chief causes of instrument failure. Minimize the effects of vibration by installing the instruments on instrument mounts—or, better yet, in locations where vibration is not present.

Keep Clean

Infiltration of dirt causes most industrial instrument trouble next to excessive vibration. When instruments must be located in dust-filled atmospheres they are usually provided with dustproof cases. Such instruments should be opened infrequently—and then preferably in a room where care can be taken to keep the parts clean.

Avoid Excessive Temperatures

Excessive temperatures, both high and low, must be avoided at the point where the instrument is installed. Instruments are built to give best operation at room temperature, approximately 70° F., and prolonged use at extreme temperatures affects instrument accuracy.

Corrosion

The operation of any instrument, regardless of its function, will be impaired if it is

located in a corrosive atmosphere. Corrosive fumes attack instrument finish, moving parts, and measuring systems—and may cause measuring error or erratic performance.

Miscellaneous

Excessive moisture will often harm industrial instruments. For installations where moisture cannot be avoided, a protecting case is recommended.

Do not expose instruments to strong magnetic fields.

When installing or relocating instruments, make sure all connections are tight and free from dirt and moisture.

Store charts in a cool, dry place. Keep charts flat, preferably in their original package, until used. When recording instruments are out of service for any considerable length of time, shut off power to the instrument and remove ink from the pens.

Be sure the instrument has ample overrange protection to prevent blowout at any pressure likely to be applied to the equipment or the line.

Fluid Pulsation

Fluid pulsation is another cause of inaccuracy and short life of pressure instruments. A shutoff valve placed ahead of the gage, and throttled until the pulsation stops, will overcome the condition but may result in clogging of the small opening. Gage snubbers have been used to overcome pulsation. One type uses a large number of small passageways with changes in direction; in another, the inertia of a moving piston prevents rapid pulsation; and a third type employs a rubber diaphragm with the gage tube filled with glycerin, the latter throttled by passing through a felt retainer.

Value of Federation Membership Demonstrated

In contrast to the inflation item with which this section opened, consider the following. A few pages farther on, in the Consolidated Membership Directory to be exact, is proof positive of the value now inherent in Federation membership. Notice the MacSo-and-sos—good Scotsmen all, from MacCullum to MacRostie—who, with true instinct, recognized a value when they met one. And then further down the column notice the 106 McSo-and-sos, who also know a good thing when they find it. Of course, in this latter group there are some Irish—McAuley, McCreary, and McNamara, to name a few—which only proves the point!

Editorials

MORE EMPHASIS ON BIOLOGY

Of recent years there has arisen a friendly feud among sanitary engineers and chemists engaged in the sewage works field, predicated upon the relative importance in this work of the two professions. The chemical engineers, who claim to embody the better elements of both professions, referee the debate with tolerant condescension.

There are indications, however, that a third specialist—the biologist—is finding greater interest and opportunity in the problems of waste treatment and stream pollution control. There may come a day when he will be represented in the field in sufficient numbers to claim that his contributions belittle the offerings of the chemist and sanitary engineer. Let us hope that this happens soon (so long as the rivalry stays friendly), because we have much to learn from the biologist.

In a recent issue of THIS JOURNAL, W. B. Hart observed that biological parameters of stream condition are perhaps more informative than are chemical parameters, but that both are important. Bartsch, in this issue, states that present biological determinations lack definition and refinement, yet his paper is an excellent demonstration of the practical application of the science. Improved procedures and specific biological standards will not be long in developing if sufficient attention is centered on this field by the biologist.

A manuscript now scheduled for publication will illustrate a case in which biological considerations govern stream requirements. A swamp stream is described, "contaminated" by solids, color and organic matter deriving from its natural environment, yet valued for its fine fishing. The point is made that the bass, bream and perch in this river have become acclimated to the natural conditions, and that the imposition of the usual water quality standards here would be unnecessarily strict and possibly detrimental to aquatic life. The view is worth considering; if we presume to set standards that will protect fish life, it is logical that we analyze such standards from the viewpoint of the fish!

Chemical analyses alone do not begin to give the complete picture of the pollutional effects of many industrial wastes. One of the greatest needs of the moment is information on the toxicity of a wide variety of elements and compounds occurring in industrial wastes, which knowledge can best be supplied through biological science.

The biological aspects of sewage and industrial waste treatment processes have by no means been ignored in the past, but we need to know a great deal more about them. When we can answer completely the what, how, who, when and why of the organisms that populate our digesters, aerators and trickling filters, we shall simultaneously solve the problems of treatment plant design and operation that are of present concern.

There is only one small detail in doubt. Who will umpire the argument when the biologist, sanitary engineer and chemist each tries to establish the leadership of his profession within the field? Possibly from this triangular union will come a hybrid technician who will style himself as a "Biochemical Engineer," to fill the breech!

WOMEN'S FEDERATION UNDERTAKES "CLEAN WATERS" CAMPAIGN

Proponents of stream pollution control received the support of a strong ally last October when the General Federation of Women's Clubs adopted "Clean Waters for America" as one of its activity programs. With a total membership of 3,000,000 women, the influence of the General Federation as exerted through its 17,000 local clubs should indeed be significant.

The campaign is being introduced across the nation by means of a series of regional conferences, the first of which was held at Philadelphia on January 16. Club presidents and Welfare Committee chairmen from eight eastern states attended the one-day meeting, which was arranged with the assistance of the Interstate Commission on the Delaware River Basin. The program, high-lighted by an address by Governor Duff of Pennsylvania, provided factual information on the stream pollution problem in the eastern region. Concluding the session, Mrs. J. L. Blair Buck, president of the General Federation, instructed the delegates to inform themselves concerning stream conditions in their home localities, and to support aggressively every effort to correct municipal and industrial pollution.

It is interesting to note that this campaign is a byproduct of the article "Foul—But You Drink It!" which appeared in a recent issue of *The Woman's Home Companion*. Although this piece has stirred considerable resentment among water works technicians because of its definitely unfair reflection on the fine work that is being done in protecting public water supplies, it appears to have been an effective alarm in awakening the feminine citizenry to the pollution menace.

The General Federation realizes that its newest project will require time, and has laid its plans on the basis of a 5-year agenda.

During his representation of the FSWA in the program of the Philadelphia "Clean Waters for America" conference, the writer reached the opinion that the women's clubs represent a tremendous force, which could be of infinite value in securing public approval and support of local pollution abatement projects. The force needs direction, however, through proper guidance and a sound background of facts and figures. Such guidance must come from informed technical sources.

All state and interstate pollution control agencies will do well to follow the example of the Interstate Commission on the Delaware River Basin in cooperating with the international women's organization. Authoritative speakers will be needed, with other assistance in setting up the regional conferences. The club officials must be informed as to where they may secure accurate and unbiased data on the needs of specific cases. Then, when the campaign reaches the local level, it will be of maximum effectiveness.

W. H. W.

Proceedings of Member Associations

NORTH DAKOTA WATER AND SEWAGE WORKS CONFERENCE

Nineteenth Annual Convention

Grand Forks, North Dakota, September 25–26, 1947

The 19th Annual Convention of the North Dakota Water and Sewage Works Conference was held September 25–26, 1947, at the Dacotah Hotel, Grand Forks, North Dakota. A total of 110 members and guests registered.

The convention was called to order by President Klivens, Grand Forks, who introduced Mayor Boe, of Grand Forks. Following the Mayor's welcome, President Kliven conducted a business session during which the reports of the Secretary-Treasurer, the Standing Committee, and the Garbage Committee were presented.

The program of the afternoon session provided the following papers:

"The Relation of Water and Sewage Works Men to the Health Department" by Russell O. Saxvik, M.D., State Health Officer, Bismarck, N. D.

"The Grand Forks Water Treatment Plant" by R. M. Jensen, Grand Forks, N. D.

"The Bald Hill Reservoir" by Col. W. K. Wilson, Jr., C. E., District Engineer, St. Paul.

"Public Relations" by Myron H. Atkinson, Executive Secretary, North Dakota League of Municipalities, and City Auditor, Bismarck, N. D.

"Some Practical Observations on Fundamental Principles of Sewage Plant Design and Operation" by W. W. Towne, State Sanitary Engineer, Pierre, S. D.

At the annual banquet, 25 past presidents were honored with the presentation of past-president pins. This ceremony followed the address of W. H. Wisely, FSWA Executive Secretary-Editor, on "Observations of an Operator on Public Relations." Elder Lium, Grand Forks, was the toastmaster for the evening.

Informative topics discussed the second day of the conference included:

"Concrete and Its Resistance to Various Gases" by William N. Gahr, Senior Sanitary Engineer, N. D. State Department of Health.

"Sulfur Dioxide in the Cleaning of Filter Beds" by Robert J. Yaeger, Ansul Chemical Company, Marinette, Wis.

"Recarbonation Equipment and Safety Measures" by Herbert J. Arnold, Lignite Combustion Engineering Corporation, Bismarck, N. D.

"Secondary Sewage Treatment for Smaller Municipalities" by George J. Toman, Mandan, N. D.

"A Preliminary Report on High Nitrates in Well Waters in Minnesota" by Herbert M. Bosch, Director, Division of Sanitation, Minnesota Department of Health, Minneapolis, Minn.

The business luncheon and election of officers concluded the conference. Officers elected to serve for 1947–48 were:

President: R. J. Lockner, Cooperstown

Vice-President: George J. Toman, Mandan

Secretary-Treasurer: Jerome H. Svore, Bismarck

JEROME H. SVORE,
Secretary-Treasurer

OHIO CONFERENCE ON SEWAGE TREATMENT

21st Annual Meeting

Columbus, Ohio, October 2–3, 1947

The 21st Annual Meeting of the Ohio Conference on Sewage Treatment was held at the Deshler-Wallick Hotel in Columbus on October 2–3, 1947. Registration included 153 members and guests. The total number of active members of the Conference increased to 208 as a result of the meeting.

The morning session on October 2 was devoted to a Manufacturer's Forum with various representatives leading the discussions. Since the annual meeting of the Ohio Section of AWWA and the Ohio Conference on Sewage Treatment were held on successive days, an overlap was planned during the Forum. "The Pipe Symposium" presented the relative merits of steel, reinforced concrete, cast iron, cement asbestos, and clay pipe. It appeared on both programs and proved of mutual interest to the members of both groups. Following this, "Advancements in Sewage Treatment and Maintenance Problems" were discussed.

The afternoon session was formally opened by Chairman L. C. Huffman and an address of welcome was given by James A. Rhodes, mayor of Columbus. At the business meeting the following officers were elected to serve during the year 1947–48:

Chairman: L. B. Barnes, Bowling Green

Vice-Chairman: E. F. Wittmer, Marion

Secretary-Treasurer: G. A. Hall, Columbus

During the business meeting F. D. Stewart, assistant chief engineer of the Ohio Department of Health, was voted the Kenneth Allen Award for 1948. In addition, a constitutional amendment was adopted conforming with the Federation's constitution regarding the dates for payment of dues.

Chairman Huffman presided at the technical sessions that followed. E. F. Wittmer's paper "Stage Filtration at Marysville Sewage Treatment Plant" presented the analytical results from alternation, during the year, of the sequence of the two-stage filters which were designed for standard loadings. He concluded that the treatment of sewage containing considerable milk wastes by two-stage filtration is slightly more effective in reducing the B.O.D. when the sequence of stages is alternated than when no change is made. In addition, some improvement in control of ponding and decrease in filter flies were noted with the change in dosing sequence.

Dr. A. H. Trebler, of Baltimore, Md., in discussing "Milk Waste Treatment," presented the operating results of several milk waste treatment plants. Charts and slides were also presented showing the milk losses and flows of different types of processing, as well as the results of laboratory test work involving flow equalization of the wastes with aeration.

C. E. Bauer presented "Experiences Using Ozone and Air in the Activated Sludge Process" at Celina. The results from the pilot plant used for the tests were subject to limitations and though some facts were interesting, no definite conclusions could be made from these studies.

The "Report on Short Schools for Operators" was presented by T. C. Schaetzle of Akron, chairman of the Education Committee. The fifteen existing short schools for operators were reviewed. The comprehensive report recommended that a committee be appointed to establish such a school in Ohio with the Ohio Department of

Health and Ohio State University as sponsors. Pertinent discussions followed and approval by the membership authorized the initiation of a program as suggested.

At the evening banquet, W. H. Wisely, FSWA, Executive Secretary-Editor, spoke on "Public Relations From the Sewage Plant Operator's Standpoint" and Maurice Le Bosquet, U.S.P.H.S., discussed "Proposed Federal Legislation Regarding Stream Pollution." This rounded out a full day of interesting facts for those attending.

The morning session of the second day began with M. L. Riehl, chief chemist, Division of Laboratories, Ohio Department of Health, who presented "Analytical Procedures for Determination of Metals Affecting Sewage Treatment." The complexities and difficulties encountered in securing reliable results were revealed and then were capably discussed by Dr. L. K. Herndon, Ohio State University, Columbus, Dr. R. C. Weast and Prof. George E. Barnes of Case Institute of Technology, Cleveland, and Walter E. Moline, National Cash Register Company, Dayton, Ohio.

B. A. Poole, Director, Division of Sanitation, Indiana State Department of Health, presented a paper, "Stream Pollution Abatement Program in Indiana," relating progress under supervision of the Stream Pollution Control Board. F. H. Waring, Chief Engineer, Ohio Department of Health, discussed stream pollution abatement under the existing state laws.

The closing afternoon session included the presentations of "The Small Plant Laboratory" by C. E. Britt, Plaskon Division, Libby Owens Ford (formerly superintendent-chemist at Bowling Green sewage treatment plant), and "Guided Discussions on Sewage Treatment" under the able guidance of A. H. Niles, of Toledo. Time, as usual, did not permit answering all of the questions.

In closing the two-day meetings some real gains had been made, but there still remained some unsolved problems and plenty of new work to be done by the Ohio members and the new officers for the coming year.

G. A. Hall,
Secretary-Treasurer

MISSOURI WATER AND SEWERAGE CONFERENCE

Twenty-Third Annual Conference

Jefferson City, Missouri, October 27–28, 1947

The 23rd Annual Meeting of the Missouri Water and Sewerage Conference was held at the Hotel Governor, Jefferson City, Missouri, on October 27 and 28, 1947. Registration of members and guests totaled 195 and represented an increase over the 1946 Conference attendance.

President Vester Opie, Paris, Mo., opened the Conference and presented Mayor James T. Blair, of Jefferson City, who welcomed the conference members. H. O. Hartung, St. Louis Water Co., presided over the joint morning technical session at which the following papers were presented:

"Protection of Water and Sewerage Facilities Against Corrosion" by A. H. Reynolds, Dearborn Laboratories, Chicago, Ill.

"Are You Prepared for a Catastrophe?" by W. Scott Johnson, Chief Public Health Engineer, Missouri State Board of Health.

"Cuprose, Its Use in Control of Algae and Insect Growth" by Max Gilfand, Dallas Power and Light Company, Dallas, Texas.

The sewerage section met in separate session on the afternoon of the 27th, with William Kehr, Principal Sanitary Engineer, Missouri State Board of Health, presiding. Albert. Happy, Missouri State Board of Health, discussed "The Effect of Garbage on Sewage Treatment Plants." F. E. Wenger, of the Russell & Axon consulting engineering firm, St. Louis, Mo., touched on current problems in his paper, "Construction and Maintenance of Sewage Treatment Plants." The session was concluded by the description of "The Accelo Filter System" by L. K. Cecil, of Infilco, Inc.

The annual business session of the Conference followed a very successful barbecue dinner. The following officers were elected for 1947-48:

Chairman: Garvin H. Dyer, Independence, Mo.

Vice-Chairman: Emmett E. Gamet, Mo.

Secretary-Treasurer: Warren A. Kramer, Jefferson City, Mo.

FSWA Director: John K. Frei, Springfield, Mo.

The morning session of the second day also was a joint session, presided over by Harvey Wilke, Missouri State Board of Health. Professor L. J. Murphy, College of Engineering, University of Missouri, started the program with his discussion of "A Proposed Streamlined Water Works Course." "Swimming Pool Water Purification Contrasted with Water Purification for Potable Use" was the title of the paper of Chauncey Hyatt, Chicago, Ill., who was followed by William J. Downer, Asst. Chief Sanitary Engineer, Illinois State Health Department, Springfield, Ill., speaking on "The Importance of Obscure Water Borne Diseases to Water and Sewage Works Operators."

With John Frei, Springfield, Mo., acting as chairman, the afternoon session of the Sewage Section proved to be one of exceptional interest and value. The first paper was on "Accounting for Sewer Systems and Sewer Rates" by F. M. Veatch, of Black and Veatch, Kansas City, Mo. Federation President George S. Russell gave a stimulating talk concerning "What the Federation of Sewage Works Associations Means to the Missouri Conference."

The panel session of "Stump the Experts," which concluded the afternoon program, provided an especially interesting and helpful exchange of information on sewage works operation and maintenance problems. Serving as "Experts" were: W. Scott Johnson, Missouri State Board of Health; George S. Russell, President FSWA; F. M. Veatch, Kansas City, Mo.; William Q. Kehr, Missouri State Board of Health; and Prof. L. J. Murphy, University of Missouri.

The Annual Conference Banquet on the evening of the 28th was an outstanding event. Vester Opie, Paris, Mo., presided. The Annual Awards presentation highlighted the evening. E. E. Gamet, Canton, Mo., was presented the Conference's Award of Merit in recognition of his heroic work during the 1947 Mississippi River floods. The Fuller Award of the AWWA was presented to Thomas Skinker, St. Louis, Mo., and announcement was made of the nomination of William Q. Kehr, Missouri State Board of Health, for the FSWA Kenneth Allen Award which is given for outstanding work in a Member Association.

Following presentation of the annual awards, brief talks were given by N. T. Veatch, president of the AWWA, and by George S. Russell, president of the FSWA, on trends in the water works and sewage works industries. The main speaker of the program, Dr. A. C. Magill, Southeast Missouri State College, Cape Girardeau, provided a fitting climax to the Annual Banquet and the Conference with his excellent talk "Public Relations."

WARREN A. KRAMER,
Secretary-Treasurer

MEMBER ASSOCIATION MEETINGS

Association	*Place*	*Time*
Kansas Water and Sewage Works Association	Hotel Broadview, Wichita, Kansas	March 11–12, 1948
Arizona Sewage and Water Works Association	New Dominion Hotel, Globe, Arizona	April 2–3, 1948
Montana Sewage Works Association	City Auditorium, Livingston, Mont.	April 8, 1948
Arkansas Water and Sewage Conference	University of Arkansas Campus, Fayetteville, Arkansas	April 12–14, 1948
Maryland-Delaware Water and Sewerage Assn.	Lord Baltimore Hotel, Baltimore, Md.	Apr. 15–16, 1948
New England Sewage Works Association	Marlborough Country Club, Marlborough, Mass.	May 12, 1948
Pacific Northwest Sewage Works Association	Hotel Boise, Boise, Idaho	May 12–15, 1948
New York State Sewage Works Assn.	Hotel Niagara, Niagara Falls, N. Y.	June 4–5, 1948
Florida Sewage Works Association	University of Florida, Gainesville, Florida	June 7–12, 1948
Central States Sewage Works Association	Milwaukee, Wisconsin	June 18–19, 1948
Ohio Conference on Sewage Treatment	Dayton-Biltmore Hotel, Dayton, Ohio	June 23–25, 1948
Kentucky-Tennessee Ind. Wastes and Sewage Works Assn.	Chattanooga, Tenn.	Aug. 23–25, 1948
Pennsylvania Sewage Works Association	Nittany Lion Inn, State College, Pa.	Aug. 25–27, 1948
Iowa Sewage Works Assn.	Hotel Kirkwood, Des Moines, Ia.	Sept. 14–15, 1948
West Virginia Sewage and Industrial Wastes Conference	Stonewall Jackson Hotel, Clarksburg, W. Va.	Sept. 30–Oct. 2, 1948
Arizona Fall Conference	Phoenix, Arizona	Oct. 15–16, 1948
Federation of Sewage Works Associations	Statler Hotel, Detroit, Mich.	Oct. 18–21, 1948
Michigan Sewage Works Association	Statler Hotel, Detroit, Mich.	Oct. 18–21, 1948

Federation Affairs

DETROIT CONVENTION TAKING SHAPE

Plans for the Twenty-First Annual Meeting of the Federation of Sewage Works Associations, to be held at Detroit, Mich., on October 17–21, 1948, are now definitely in the creative stage. The live-wire Michigan Sewage Works Association will be host to the Federation, and will hold its 23rd annual business meeting during the national convention.

Headquarters for the meeting will be the Hotel Statler, where all technical sessions, exhibits, and social events will be held. Adequate accommodations have been assured at the Statler and other Detroit hotels.

Chairman of the Local Arrangements Committee is W. M. Wallace, superintendent of filtration and sewage treatment at Detroit. The following local committee appointments have been made:

Registration: G. R. Thompson, chairman, C. L. Palmer, M. F. Wagnite, G. E. Hubbell, and H. M. Leonhard.

Hotel Arrangements: F. G. Legg, chairman, R. Chapin, E. G. Liddle, M. S. Hilbert and N. Herda.

Finance: W. E. Smith, chairman, W. C. Hirn, V. Anderson and J. S. Perry.

Inspection Trip: Leroy Smith, chairman, F. H. Burley, C. A. Habermehl, J. E. Cooper and M. A. Groen.

Entertainment: Chairman to be appointed, F. W. Dubois, E. L. Dingler, Jr., W. D. Wilt and M. A. Groen.

Local Host: W. F. Shephard, chairman, E. A. Boyce, Don Pierce, H. E. Potts, A. T. Kunze, J. M. Hepler, E. C. Rich, L. G. Lenhardt, L. A. Oeming, E. E. Eldridge, M. P. Adams, R. A. Greene and W. C. Dalee.

Chairman C. C. Larson of the Publications Committee has appointed F. W. Gilcreas to head a special program committee, and formulation of the technical program is proceeding. The time-table of the meeting provides for five half-day technical sessions in addition to a full afternoon for an inspection trip of the Detroit and Dearborn sewage treatment plants. One of the technical sessions has been set aside for the new Industrial Wastes Forum, which is expected to be an outstanding feature. The concluding session on Thursday morning, October 21, will be devoted to the Operators' Forum, a program highlight of past meetings.

The Annual Federation Luncheon will be held on Tuesday, October 19. It is planned to secure a prominent speaker for this occasion.

General entertainment and social events will include a reception-entertainment and a dinner-dance. Another evening function will be the Michigan Dinner and Business Meeting, for members of the host association and their guests.

The Ladies Committee is in process of appointment. With all of the points of interest and fine shopping opportunities in Detroit, there may be assurance that an attractive schedule of ladies entertainment events will be forthcoming.

A large and diversified manufacturers' exhibit is expected to develop under the direction of Arthur T. Clark, secretary-manager of the Water and Sewage Works Manufacturers Association.

Everyone planning to attend the convention is urged to act early in making hotel reservations. Rates at the Statler are: single—$3.50 to $5.00 (with shower) and $5.50 to $8.00 (with tub and shower); double—$6.00 to $10.00; double (twin beds)—$7.00 to $10.50; suites—$12.00 to $20.50. Reservations may also be placed with the Book-Cadillac Hotel, which has also assigned rooms for use during the convention.

A registration at or above the record of 812 set at Toronto in 1946 is expected, because of the central location of Detroit. Officials and local members of the host Michigan Association are determined that this meeting shall maintain the high standard of excellence of previous Federation conventions.

STANDARD METHODS RESEARCH PROJECT IN OPERATION

Active research is now going forward in the six laboratories participating in the project being sponsored by the Federation and financed by the National Institute of Health for the investigation of analytical methods for sewage and industrial wastes. Although the federal grant covering the project became effective on September 1, 1947, difficulties in securing competent personnel to carry on the work delayed actual initiation of several of the laboratory studies until February of this year. The project is being directed by Dr. W. D. Hatfield, chairman of the FSWA Committee on Standard Methods.

The location, directors, and general assignments of the six laboratories are as follows:

Lab. No. I—University of Wisconsin; Dr. M. Starr Nichols; B.O.D. studies along the lines of those being undertaken at M.I.T.

Lab. No. II—Illinois State Water Survey; Dr. A. M. Buswell; colorimetric and titrametric methods for ammonia, nitrites and nitrates. Also B.O.D. studies on seeding and suppression of nitrification.

Lab. No. III—Allegheny County Sanitary Authority; H. Gladys Swope; analytical methods for metallic and inorganic industrial wastes; toxicity determinations, etc.

Lab. No. IV—Rutgers University; Dr. Willem Rudolfs; B.O.D. by direct oxidation, as applied to sewage and industrial wastes, and in comparison with the dilution method. Also studying toxicity determinations.

Lab. No. V—New York State Department of Health, Laboratory of Hygiene and Research; F. W. Gilcreas; methods for determining grease, ammonia, chlorine demand, residual chlorine, and stability.

Lab. No. VI—Massachusetts Institute of Technology; Dr. Clair N. Sawyer; B.O.D. studies, including dilution water, seed, suppression of nitrification, standardizing of salts and solutions.

Under an agreement executed in 1947, the Federation will be a joint publisher with APHA and AWWA of the tenth edition of *Standard Methods for the Examination of Water and Sewage.* The results of the NIH research project should be available for inclusion in the tenth edition, which will make that manual particularly significant and valuable.

The preparation of the tenth edition will be managed by a Joint Editorial Board consisting of representatives of each of the participating associations. Dr. Hatfield will serve the Federation on this board, with Mac Harvey McCrady for APHA and Harry A. Faber for AWWA.

Reviews and Abstracts*

Kanawha Basin Zoning Report. WEST VIRGINIA WATER COMMISSION. Charleston, West Virginia (July 1, 1947).

West Virginia's proposed program for pollution abatement in surface waters of the state is described and the pollution conditions in the streams of the Kanawha Basin are set forth with the aid of detailed charts, graphs, tables and maps. Special attention is devoted to the conditions in the lower Kanawha River where pollution is most intense.

Under the West Virginia Water Commission Act of 1945 the Water Commission has devised a program for the protection and improvement of natural surface water resources of the state. The major projects now under way are:

1. Classification of every mile of every major stream in the state into one of four water-quality zones.
2. A cooperative program of improving industrial stream pollution to an acceptable degree by the installation of waste recovery and treatment units.
3. A program of educating and encouraging the municipalities of the state to undertake planning toward sewage treatment.

The criteria for zoning or classification of West Virginia streams into four groups: AA, A, B, and C, as well as methods and accuracy of stream zoning are discussed. These criteria include: (1) most probable number of coliform bacteria per 100 ml., (2) dissolved oxygen, (3) five-day B.O.D., (4) pH, (5) fluorides, (6) chlorides, (7) phenolic compounds, (8) iron, (9) color, (10) turbidity, (11) industrial or domestic sludge deposits, and (12) other conditions, including toxic substances, oils, tars, mineral acids, floating solids, and taste and odor producing substances. This report on the Kanawha Basin is the first zoning report issued by the Commission.

An attempt to gain the cooperation of offending parties in the pollution abatement program is being made. If cooperative methods fail, legal action will be taken.

The degree of treatment required of each case will be determined by the Health Department and Water Commission. State approval is necessary on all new outfalls.

Each offending municipality and industry is requested to define its problem and determine the best method of correction. Water Commission personnel will be available for consultation and general assistance. The Commission is working with new industry coming into the state to aid new plants in the provision of adequate waste treatment facilities.

The Commission seeks to encourage municipal planning for sewage treatment through conference with official families of the municipalities. West Virginia now has less treatment than any other state in the Ohio Basin but all of the state's large cities and many towns are now planning for sewage treatment. All new industries in the state are installing waste treatment facilities.

The purpose of the Commission's reports is the definition of stream conditions in all major streams of the state and with the publication of this report the initial stream definition task is 35 per cent complete. During the summer of 1947 sufficient sampling and analysis is contemplated to allow completion of classification of the Little Kanawha, Guyandot, Big Sandy, and Potomac Basins. Reports will be published as soon as possible. Follow-up sampling and periodic zoning revisions will be made thereafter.

The Kanawha and its tributaries serve as a water supply and a means of waste disposal for municipalities, industries, and

* Please send to Federation headquarters all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in THIS JOURNAL. Publications of public health departments, stream pollution control agencies, research organizations, and educational institutions are particularly desired. Address such material: Federation of Sewage Works Assns., 325 Illinois Bldg., Champaign, Ill.

railroads of the area. The water courses are also employed for fishing and recreational purposes. Maps and graphs were developed to give an indication of existing conditions along the streams of the watershed. Treatment priority lists have been made for those industries and municipalities which are responsible for serious pollution and those which may, in the future, be required to inaugurate a pollution control program.

H. B. GOTAAS

Report upon the Collection, Treatment, and Disposal of Sewage and Industrial Wastes of Orange County, California. BY A. M. RAWN, C. G. HYDE AND F. THOMAS. 46 p., lithoprint, June 30, 1947.

This is a very complete report on an area of 800 sq. mi., with a population of 200,000 (est. 1947), including 13 cities with a population of 114,000. The population is estimated to increase from 130,760 in 1940 to 290,600 (1950) and 802,800 (1970). The ocean shoreline is about 42 mi., with many beaches used for recreation. There are three major drainage basins. Annual rainfall varies from 12.34 to 22.75 in. with very little from May to October. In certain sections there are 320 days with more or less sunlight. The climate is very temperate, varying from 56.1° to 68° F. on seasonal averages.

Detailed investigation indicates an average volume of industrial wastes of 4.1 m.g.d. (1947) or 21.5 g.p.c.d. Domestic sewage is estimated at 70 g.p.c.d. except at Newport Beach (140 g.p.c.d.). In some sections 50 g.p.c.d. is estimated. The ground water infiltration is taken at 50 g.p.c.d. Treatment works are suggested for design on a 20-year basis, built in 10-year increments, and other works some 40 years ahead. Industrial wastes in 1947 had a 5-day B.O.D. of 93,500 lb., contributed by seasonal industries including beet sugar, citrus byproducts, fruit and vegetable processing.

To determine the location of an ocean outfall a comprehensive study of the ocean currents was made, since the premise was adopted that the shore waters and shores should be maintained clean, unpolluted, and suitable for unrestricted use. Floats were released at many locations along the shore within a 3-mi. zone. Currents were found to be rotary in nature, with a direction constantly changing clockwise and with a daily cycle. The tidal current varied from 4 to 31 f.p.m. The wind currents were estimated at 33 f.p.m., with the wind onshore by day and offshore at night. By combining the components due to tides, daily periodic winds, ocean drift, and nonperiodic winds, a basis for outfall location was obtained. There is an additional movement at an ocean outfall due to the hydraulic head of the rising volume of fresh water through the ocean salt water.

Currents are predominantly onshore in the daytime and offshore at night. Thus, discharge of effluents at night is desirable, with a storage basin, and chlorination to control odors.

Various types of sewage treatment were considered with the following conclusions: For Districts Nos. 1–8, one main treatment plant, including grease removal facilities discharging through a 15,000-ft. outfall. For District No. 9, primary treatment with a 2,000-ft. outfall. For District No. 10, an Imhoff tank, open air sludge-drying beds, and oxidizing ponds with recirculation and discharge to Santiago Creek. If the sewage is reclaimed for irrigation or ground-water replenishment, complete treatment (as by the activated sludge process) with chlorination of the effluent will be necessary. Costs were estimated with an E-N-R index of 350.

Although ground garbage may be added to sewage from home grinder units in gradually increasing quantities, the future of such practice is not clear enough to influence current design of the proposed treatment plants.

Administration of the 10 proposed districts should be vested in one central organization. The cost of money for project financing was taken at 2 per cent, with bonds of the 40-year serial type.

In the maintenance of the sewers, sulfide control will be necessary by chlorine, applied in the ratio of 3 p.p.m. for each 100 p.p.m. of B.O.D. in excess of that which the sewage velocity would control without treatment.

Concerning sewage reclamation as related to water supply, the report concludes that the excessive costs involved in producing an acceptable effluent, the limited

availability of spreading-ground with respect to both areas and period of use, together with the hazard of introducing boron into the underground waters, combine to make the use of reclaimed sewage by the method of percolation impracticable. The cost of reclaiming sewage would be of the magnitude of twice the cost of purchasing fresh water.

The report recommends the County Sanitation District Act of May, 1923, as most applicable to the regional sewerage problem of Orange County.

The problems of planning, construction, financing, and operation are covered in detail.

In particular, the relation of sewage disposal to bathing beaches is discussed in detail because of the use and importance of Orange County beaches. In the summer of 1940, 950,000 people used Newport Beach. Probably 250,000 people use the beaches on a typical summer Sunday. At present, beach pollution is serious. The effect of currents from the sewer outfall has been studied with the use of pellets. Data from the records of the Orange County Health Department are presented, from samples collected at knee depth, on *B. coli*, as determined by the presumptive test using 2 tubes each of 1.0 ml., 0.1 ml. and 0.01 ml. with 48-hr. incubation. Pollution is considered to be indicated when the most probable number (m.p.n.) of coliform organisms per ml. exceeds 10 for 20 per cent or more of the samples.

The areas of the survey are served at present by 10 municipal sewage treatment works and three military installations. All sewage is clarified and chlorinated. In addition, four municipal plants have trickling filters; one, activated sludge treatment. There are five ocean outfalls and two river outfalls. Under the proposed plan there will be two ocean outfalls, and one inland discharge. In 1946 the sewage at the existing main outfall had a B.O.D. of 560 p.p.m. and a chlorine demand of 47.6 p.p.m. The chlorine applied was 11.65 p.p.m. The sulfate content was 228 p.p.m.

The report contains a mass of detail which may interest specialists. The first 25 pages of findings and 2 pages of recommendations condense the material.

LANGDON PEARSE

Santa Clara County (Calif.) Sewage Disposal Survey. By C. G. HYDE AND G. L. SULLIVAN. Planograph, 191 pp. (with Appendices I to XX). (July 31, 1946).

This report covers the collection, treatment, and disposal of sewage and industrial wastes of Santa Clara County, Calif. The county has an area of 1305 sq. mi., with a 1940 population of 175,000, of which 109,000 are incorporated municipalities. During the ten-year period 1935–1944, the lowest monthly average temperature was 42.2° F., and the minimum day 22°. The rainfall is chiefly distributed through nine months of the year.

Seven County sanitation districts are tributary to a proposed central sewage treatment works.

There are some 65 industrial establishments, mostly processing fruit and vegetables. Twelve municipalities have sewer systems. In the San Jose area, the domestic sewage averaged 93 g.p.c.d., as compared with a water use of 115 g.p.c.d. The industrial flow for two weeks averaged 144 g.p.c.d. The total equivalent population (including domestic) for nine months averaged about 420,000, with a peak average for three months of about 750,000.

The territory drains into Lower San Francisco Bay, a tidal estuary which is grossly polluted during the canning season. Complete treatment is required. Various types of treatment are considered, including oxidation ponds. Nine projects are outlined, of which the one recommended comprises preaeration and primary sedimentation tanks, oxidation ponds and recirculation, sludge digestion tanks, and disposal lagoons with chlorination equipment. Estimated total cost for trunk sewers and treatment is $4,842,000.

Cost of operation and financing is discussed in detail, outlining the California requirements for sanitation districts and sewer service charges.

The 20 appendices cover the history, description, and discussion of sewerage and sewage disposal in the 19 municipalities concerned. One appendix, by Rawn, covers governmental organization and method of financing.

LANGDON PEARSE

Thirteenth Report of the Water Pollution Research Board with the Report of the Director of Water Pollution Research (England), July 1, 1939 to December 31, 1945, 78 pp.

The introduction stresses the development of industrial waste control and legislation relating to Scotland known as the Rural Water Supplies and Sewerage Act, 1944, covering grants to rural authorities, and the Water Act, 1945, relating to coordination of water supply services. In cooperation with the Agricultural Research Council, research has been conducted on the use in agriculture of dried sewage sludge and of various composts. Various studies have been conducted, in collaboration with municipal authorities, on flies from trickling filters, chlorination of water, and corrosion of domestic water supply installations. A temporary laboratory has been maintained for sewage work. The war interfered with research projects except as to alternating double filtration of sewage. Future work in the field of microbiology is recommended.

In the sewage field, biological filtration was tested at Birmingham in a process of alternating double filtration, applying settled sewage to a primary trickling filter-humus tank, the effluent passing to a secondary filter and humus tank. After a certain interval the order was reversed. At first the change was made weekly, later daily. Some of the more important results were as follows (using 4 unit filters, each of 1,100-sq. yd. area, 6 to 7 ft. deep):

	June 1940 to May 1941	June 1941 to May 1942	June 1942 to May 1943	June 1943 to May 1944
Rate of filtration (Gal. per cu. yd. per day):				
Single filtration	72– 97.2	93.6– 99.6	75.6–100.8	69.6– 93.6
Alternating double	192–195.6	252 –258	289.2–307.2	282 –292.8
B.O.D. (p.p.m.)				
Settled sewage	130–160	105 –150	130 –170	150 –180
Settled effluent from single filter	11– 17	9 – 13	9 – 14	7 – 10
Settled effluents from alternating double filter				
Primary effluent	16– 21	11 – 23	17 – 20	19 – 35
Secondary effluent	9– 20	6 – 12	10 – 12	9 – 14

The final effluent of the double filters contained more ammonia and less nitrate than that of the single filter.

Continuous high rate filtration with recirculation of part of the effluent was tried using rates of settled sewage of from 240 to 288 gal. per day per cu. yd. filter media. The effluent contained little nitrate and was less reliable than the alternating double filtration plant.

Observations were made on the bio-flocculation plants at Minworth.

Control of nuisance from filter flies was investigated, with the conclusion that attention should be given to the application of toxic materials to filters to kill the flies, such as DDT and Gammexone. The application of 10 lb. per acre of DDT or 5 lb. of "666" per acre seemed effective on small filters. Ten lb. of DDT per acre and as low as 1 lb. per acre of Gammexone were effective on large filters.

Bacterial and chemical changes in aerated liquids were also examined, as well as the flora of activated sludge. In the latter, 71 strains of bacteria were isolated, mostly gram-negative rods. Only a few spore-forming aerobes, moulds, and yeasts were found.

During the war the recovery of grease from sewage sludge and skimmings was tested by extraction with light petroleum (boiling range 100° to 120° C.). It was estimated that 4,000 tons per year per million persons could be recovered.

No conclusion was reached on the effect of air drying and digestion of sludge on certain pathogenic organisms or the risk involved in using such sludge as fertilizer.

Rising of sludge in sedimentation tanks at sewage works serving explosives and filling factories was due to the presence of ammonium nitrate or nitrate.

Suitable chemical closets were devised for use in air-raid shelters.

Thirty-five pages are devoted to industrial wastes. Among the topics discussed are: dairies and milk products factories (by reference); preparation of vegetables for drying; recovery of copper from waste waters from pickling operations by cooling pickle liquor to recover crystalline copper, or by cooling it after partial evaporation, or by electrolysis. In some factories waste wash waters are treated with lime, to precipitate copper hydroxide. In a few mills waste waters are passed through tanks containing scrap iron on which copper deposits. An improved design was developed, with a sludge compartment under the baled scrap iron wire.

An extended investigation was made of the treatment and disposal of sewage and waste waters from shell-filling factories, particularly those wastes from the laundries, washing of tools, floors, etc., and the washing out of rejected ammunition. The chief constituents of the waste waters were trinitrotoluene, ammonium nitrate and "tetryl." Sedimentation tanks were usually installed with balancing tanks used to distribute laundry wastes (which discharged intermittently). Laundry wastes averaged about 1.8 gal. per day per employee. The other wastes from tool washing, etc., averaged about 0.5 per cent of the total volume of sewage and waste waters in a factory.

In factories handling chiefly trinitrotoluene and ammonium nitrate, the mixed liquors and sewage averaged from 10.8 to 19.2 gal. per day per employee. Such liquids were not very high in B.O.D. (95 to 182 p.p.m.). Filtration was tried experimentally. At shell filling factories, sewage mixed with washes were treated together. Apparently TNT up to 40 p.p.m. did not inhibit growth of bacteria.

Wastes from the mixing of picric acid and dinitrophenol (shellite) were handled mixed with sewage in a local sewage works after the loss of "shellite" was cut to a minimum. Waste waters from filling smoke bombs with yellow phosphorus were piped to a sewage works for settling and discharged into a tidal estuary at ebb tide. Changes in operations in making colored smoke compositions reduced the escape of dyes to 0.8 p.p.m. in the effluent of the factory sewage works, and to 1.3 p.p.m. for entry into surface water.

A study was begun on the treatment and disposal of waste waters from the manufacture of TNT.

Investigations were made on the removal and recovery of chromium from waste waters containing chromates.

Waste waters containing cyanide are troublesome. It is very difficult if not impracticable to render them nontoxic. However, treatment with ferrous sulfate and lime may be effective. If cyanide wastes are mixed with sewage and treated on a trickling filter, 90 to 97 per cent of the cyanide may be removed.

The waste waters from "retting" of flax are acidic, with a disagreeable odor, but yield to treatment on a trickling filter, if diluted. A scheme for recirculation was suggested, with aeration.

Among other studies were those of wastes from the manufacture of brake and clutch linings; the concentration of garbage and disposal of waste waters from steam cooking; photographic processes; paper mills; 5-therm emergency producer-gas plants; predigestion of straw with caustic soda for animal feed; cellulose from sawdust; manufacture of beet sugar (summary of general practice); and viscose rayon (re-discharge of waste to sea).

The last 8 pages are devoted to the polluting effects of sewage and industrial waste, particularly on the River Avon where it was proposed to chlorinate the sewage effluent from the Coventry works. However, preliminary experiments indicated that chlorination of an effluent from treatment of sewage containing gas liquor might make the effluent toxic for fish. The project was abandoned.

An extended bibliography is appended.

LANGDON PEARSE

Control of Flies Breeding in Percolating Sewage Filters.* By T. G. TOMLINSON AND S. H. JENKINS. Presented at The Public Works, Roads and Transport Congress, July 25, 1947. (Auspices of The Institute of Sewage Purification) 32 pp.

Nuisance often results from the emergence of large numbers of flies from perco-

* A preprint.

lating (trickling) filters located near residences or streets. Species causing trouble include *Psychoda alternata*, *Psychoda severini*, and *Anisopus fenestralis*. They may cause a nuisance within a radius of 1 mile from the filter. An unpleasant aspect of the *Anisopus* is the deposition of its gelatinous egg masses on moist objects such as food and household utensils.

Various methods for the control of *Psychoda* have been tried including chemical treatment and flooding. With the discovery of DDT and Gammexane new chemical methods of attacking the problem were available. This paper describes laboratory and large-scale experiments at the Water Pollution Research Laboratory, Minworth, and at a number of sewage works, on the control of *Anisopus fenestralis* and *Psychoda* by means of DDT and Gammexane and also the work by a district drainage board on the use of gas liquor, salt, creosote and bleaching powder for control of *Anisopus fenestralis*.

To determine the effects of various treatment methods it was necessary to estimate the number of flies emerging from a unit area. This was done by counting the numbers caught in traps of known area placed on the surface. The counting methods and trapping equipment are described in detail.

Insecticide solutions were prepared as follows:

(1) Creosote: Emulsified creosote prepared by stirring 20 gal. of warm, 0.5 per cent soap solution and 0.6 gal. of 40 per cent caustic soda into 50 gal. of creosote. Emulsions containing 1 to 2 per cent by volume of creosote were prepared from this concentrated emulsion by adding water.

(2) DDT: DDT preparations having the following compositions were used: (a) sulfonated castor oil, 24.5 per cent; cresylic acid, 6.0 per cent; DDT, 15.5 per cent; solvent naphtha 54.0 per cent; (b) 1 lb. of DDT, 0.1 gal. sulfonated castor oil, and 0.4 gal. of acetone.

(3) Gammexane: (a) A preparation of Gammexane, Decalin extract LG.037, containing 7 per cent of the gamma isomer of benzene hexachloride was diluted with a mixture of acetone and sulfonated castor oil to give a solution of the following composition: Decalin LG.037 (Gammexane prep.), 14.3 per cent; sulfonated castor oil, 25.0 per cent; acetone, 60.7 per cent.

(b) 10 lb. of commercial product containing 13 per cent of the gamma isomer and known as D.929 were stirred with 2.5 gal. of warm acetone for 10 to 15 min., the liquid allowed to stand for 1 hour, the acetone solution poured off and $\frac{5}{8}$ gal. of sulfonated castor oil added. This contained about 4 per cent Gammexane.

Two methods of applying the insecticides to the filters were used, hand-spraying, and application to the filter influent.

A substantial number of laboratory and plant scale experiments were conducted and the following conclusions reached:

(1) DDT and Gammexane applied to trickling filters in the sewage in concentrations sufficient to kill over 90 per cent of the larvae of *Anisopus fenestralis* and *Psychoda alternata* had no apparent effect on *Lumbricillus lineatus* and *Achorutes subviaticus*.

(2) In the laboratory, sewage containing 0.1 to 5 p.p.m. of DDT or Gammexane, applied to filters for 1 to 24 hours, produced over 90 per cent mortality in the larvae of *Anisopus* and *Psychoda*. For *Anisopus* control, 1 to 2 lb. of Gammexane or 25 lb. of DDT per acre were necessary, whereas for the control of *Psychoda alternata* 1 lb. of Gammexane or 5 lb. of DDT per acre were sufficient.

(3) Large-scale experiments carried out in 1945 showed that treatment with 194 lb. of creosote, 3 lb. of bleaching powder, or 75 lb. of DDT per acre controlled emergence of *Anisopus*.

(4) Similar large scale experiments carried out in 1946 showed that a single application of insecticide in the form of a solution of Gammexane or of DDT added to the sewage at rates sufficient to produce 1 lb. of Gammexane or 50 lb. of DDT per acre over a period of 1 to 2 hours, was effective in controlling *Anisopus*.

(5) Spraying parts of the surface of a filter with DDT or with Gammexane at rates of 10 lb. of DDT or 1 lb. of Gammexane per acre controlled *Psychoda* for periods of 2 to 4 weeks respectively.

(6) Experiments carried out at a number of sewage plants in which the insecti-

cide was applied to circular filters in the sewage feed showed that applications of 1 lb. of Gammexane or 5 lb. of DDT per acre controlled the emergence of *Psychoda* for a period of about 4 weeks.

(7) DDT and Gammexane had no effect on the B.O.D. or oxygen absorbed values of the effluent or on nitrification, but there was evidence that effluents discharged from some filters at the time of treatment with insecticides were distinctly toxic to fish. It would not be advisable to use these insecticides on a large scale until further information on this toxicity is obtained.

PAUL D. HANEY

Toxicity to Rainbow Trout and Minnows of Some Substances Known to be Present in Waste Water Discharged to Rivers. By J. GRINDLEY. *The Annals of Applied Biology* (British), 33, 1, 103–112 (February, 1946).

The investigations described in this paper were made as a part of the research program of the British Water Pollution Research Board and were concerned with the measurement of the toxicity of several pure substances under controlled conditions. The substances tested were sodium arsenite, sodium arsenate, sodium picrate, sodium dinitrophenate, zinc sulfate, potassium chromate, potassium bichromate, ammonium chloride, and ammonium sulfate. Tests were made with distilled water, tap water, and distilled water-tap water solutions of the substances.

Tests were made to determine the maximum concentration of toxic substances which would not affect fish during periods of a few days, and it is recognized that smaller concentrations acting over long periods might also prove toxic.

Several variables influence the toxicity of solutions. They include (1) type of water in which poisonous substance is dissolved, (2) concentration of the poison, (3) temperature, (4) pH value, (5) oxygen concentration, and (6) species, size, and condition of the fish used. Unless conditions are carefully controlled, toxicity varies widely. The greatest source of error in making tests is the difference in susceptibility of individual fish.

The tap water used in these experiments had a total hardness of 278 p.p.m.; carbonate hardness, 265 p.p.m.; and a pH value of about 7.4. The distilled water was aerated prior to use. Aeration was continued during the tests.

Toxicity of a solution to individual fish was expressed as 100 times the reciprocal of the period in minutes during which each fish was immersed. The arithmetic mean of individual toxicities to all fish immersed in any given solution was called the average toxicity. The mean period of immersion of fish was taken as 100 times the reciprocal of the average toxicity. To supplement average values of toxicity, which give no indication of the scatter of results, the standard deviation from the average toxicity was calculated.

Tests on sodium arsenite were made using tap water, and it was found that neutralized solutions of sodium arsenite were more toxic to minnows than equivalent sodium arsenate solutions. Minnows survived for a mean period of 36 hours in a sodium arsenite solution (20 p.p.m. as As) and for about 16 hours in a solution of sodium arsenate (250 p.p.m. As).

Stock solutions of picric acid and dinitrophenol were prepared and then diluted with tap water to produce the test solutions. Dinitrophenol was much more toxic than picric acid at a given concentration. Extrapolation of the toxicity curves, however, indicates that both substances have nontoxic (minnows) limits of about 30 p.p.m. No fish killed by these substances recovered on removal to fresh water.

Zinc sulfate dissolved in distilled water (no pH adjustment) was toxic to rainbow trout in 133 minutes, at a concentration of 25 p.p.m. as Zn. All fish died soon after transfer to fresh water.

Toxicity tests on potassium chromate and potassium bichromate were conducted in distilled water solutions of these salts at 18° C. No pH adjustment was made. At equivalent chromium concentrations strong bichromate solutions were more toxic than chromate. The test results confirmed conclusions previously reached by Ellis that the toxicity of a solution having a pH of less than 5.0 is due in part to its acidity and that at a pH of greater than 5.0, lethality factors other than hydrogen ion concentration play the major role.

The most dilute chromate and bichromate solutions tested had pH values of

more than 5.0 and had similar toxicities to trout. The fish lived from 60 to 72 hours in solutions having a chromium concentration of 20 p.p.m. as chromium. With an increase in concentration, the pH of the bichromate solutions fell below 5.0, and these solutions were much more toxic than chromate solutions of equivalent chromium concentration. The limiting concentration for rainbow trout appeared to be slightly less than 20 p.p.m. of chromium.

In the tests on ammonium chloride and sulfate, yearling rainbow trout were used. Solutions were prepared with distilled water, tap water, and mixtures of the two waters. Temperature was maintained at 18° C. When equivalent amounts of ammonium chloride and ammonium sulfate were dissolved in the same type of water, there was no appreciable difference in their toxicity. Solutions of both were much more toxic in tap water than in distilled water. The limiting concentration for both salts in distilled water is probably slightly less than 100 p.p.m. as NH_3. In tap water ammonium chloride was found to be slightly toxic at 50 p.p.m., as NH_3.

Data are presented in tabular form and graphically. Six references are given.

PAUL D. HANEY

Cyanides in Trade Effluents and Their Effect on the Bacterial Purification of Sewage. By W. T. LOCKETT AND J. GRIFFITHS. *The Institute of Sewage Purification* * (July 25, 1947). 24 pp.

Traders within the West Middlesex drainage area submit applications in accordance with the Public Health Act for permission to discharge trade effluents into public sewers. Approval is given subject to an Agreement containing "clauses relating to the flow of the effluent to the sewers" and "clauses embodying such conditions of discharge as are required for protection of the sewers, sewage plant and processes, and for the safety of sewermen, etc."

Based upon experience and confirmed by a series of tests described in this paper, limitations have been established for effluents containing cyanide. These are predicated on adequate flow in the receiving sewer and the production of an effluent of a suitable pH value. If discharge is not to be more than a few thousand gal. per day, it may contain up to 50 p.p.m. cyanide, calculated as HCN, but if it is to be of the order of 20,000 to 50,000 g.p.d., a cyanide content of less than 30, or even 20, p.p.m. may be required.

Apparatus was set up to give a reasonably close reproduction of air conditions in sewers and studies were made under variable conditions with water and sewage solutions containing from 20 to 1000 p.p.m. cyanide, expressed as HCN. The following factors were varied: pH from 2.8 to 11.0, air and liquid temperatures from 62° to 73° F., and the rate of air passage from 1 to 25.36 cu. ft. per hour, or 3 to 71 changes of air over the liquid per hour.

Only with a concentration of 20 p.p.m. cyanide in the solution was it possible to obtain effluent air containing less than 0.030 mgm. HCN per liter. With a cyanide concentration of 30 p.p.m., effluent air contained from 0.032 to 0.053 mgm. HCN per liter, and with concentrations of 50 p.p.m. cyanide in the solution, the effluent air contained as much as 0.139 mgm. HCN per liter.

The following table was given to show the effects on humans produced by different concentrations of hydrogen cyanide vapor in air:

Concentration of HCN Vapor in Air		Effects
Parts by Vol. (Approx.)	Mg. per Liter (Approx.)	
1 in 50,000	0.025	Slight symptoms after several hours
1 in 10,000	0.12	Very dangerous in one hour
1 in 500	2.5	Fatal

Only a small reduction in the concentration of HCN in the air was obtained by increasing the rate of air passage through the equipment.

Results on sewage containing 50 p.p.m. of cyanide, expressed as HCN, indicate that lowering of pH below 7.0 will give a slightly increased quantity of hydrogen cyanide vapor in the air flow. Raising of pH above 8.0 slightly suppresses the release of vapors from the liquid to the air.

* A preprint.

The paper lists the following conclusions:

"1. That the concentration of cyanide in normal alkaline sewage flowing in large sewers in which men may have to work for periods of several hours should not exceed 1.0 part of cyanide, calculated as HCN, per 100,000 parts of sewage.

"2. That the concentration of cyanide in normal alkaline sewage flowing in small sewers (branch sewers and the like) should not exceed 2.0 parts HCN per 100,000 parts of sewage."

The stability of cyanide in sewage for periods up to three days was studied and it was concluded that there was no noteworthy chemical or biochemical change in the cyanide "during a period of time comparable to that required for the sewage to be conveyed to the sewage works and to pass through sedimentation tanks."

The effect of cyanide on anaerobic fermentation of sewage was studied using sodium sulfate and colloidal iron as indicators of putrefaction. Two series of tests were made using sieved sewage to which was added the indicators and from zero to 100 p.p.m. cyanide (expressed as HCN). Results showed that, with temperature maintained at 26.7° C., only those samples containing no cyanide decomposed rapidly and none with concentrations greater than 4 p.p.m. cyanide (expressed as HCN) showed signs of decomposing within four days.

Experiments on activated sludge were conducted in quart and 4-liter bottles into which air could be drawn. Tests were made using both Modgen treatment plant activated sludge and activated sludge produced in the bottles. To the sludge remaining after supernatant liquors were removed, further quantities of sewage alone and sewage plus cyanide were added, and aeration resumed for periods from 6 to 22 hours. Results clearly show that with a concentration of 5 p.p.m. cyanide (as HCN) in the sewage added to the activated sludge, although much cyanide is blown off as HCN, that which remains has a marked inhibitory effect on the purification process. No lower concentrations of cyanide were tried.

Attempts to acclimatize the sludge to cyanide by using successive volumes of sewage plus cyanide in the aeration bottles failed, so tests were then made to determine if activated sludge could be built up afresh from sewage containing low concentrations of cyanide. It was determined that 1 p.p.m. of cyanide expressed as HCN in the sewage will retard the rate of building up of a good activated sludge. A satisfactory sludge was finally obtained after 75 fillings of the aeration bottle, but upon increasing the dosage to 2 p.p.m., cyanide (as HCN) purification was again retarded and, even after continued aeration through a total of 277 fillings, the sludge was not satisfactory.

The effect of cyanide on the purification process depends to some extent on the proportion of sludge to the sewage employed. There was a considerable improvement in the results of aeration of sewage containing 2 p.p.m. cyanide when the percentage of sludge in the mixed liquor was increased from 7 to 22 per cent.

Another test indicated that cyanide in low concentrations has an inhibitory rather than a lethal effect on bacterial life, and that, following elimination of cyanide from the sewage, the sludge rapidly recovered its activity. For this test sewage containing 20 p.p.m. cyanide as HCN was used.

It was noted that in all the experiments the activated sludge used was highly active and that under normal plant operation lower concentrations of cyanide than those reported on favorably in the tests might have some deleterious effect on the sewage works bacterial purification process.

W. A. HASFURTHER

Recent Advances in the Treatment of Sewage by Biological Filtration. By B. A. SOUTHGATE. *Journal of the Royal Sanitary Institute*, 67, 3, 169–176 (May, 1947).

Research work on biological filtration has led to major advances in the use of this type of waste treatment. This paper summarizes briefly the advances made in recent years in this field.

When study of improvements in biological filtration was begun it was general practice to pass the settled sewage through a single trickling filter or a number of

filters in parallel. It was generally agreed that efficient distribution of the sewage was important, that the media should be properly graded, and that there should be adequate facilities for natural ventilation. Filters averaged around 6 ft. in depth. Factors known or thought to affect the rate of treatment were degree of aeration, temperature, and growth of biological film. The improvement problem centered around modifications in design or operation which would permit reduction in cost.

The problem of increasing the overall rate of dosage is often not that of increasing the working efficiency of the biological film but of retarding its growth so that the filter does not become clogged. One process which enables sewage to be treated in trickling filters at a high rate without excessive film growth is that of filtration with recirculation of effluent. Interest in this process dates from American experiments on a semiworks scale in 1937. In 1941 large scale experiments were begun by the Water Pollution Research Laboratory. In these experiments effluent from a filter, after sedimentation, was mixed with an equal volume of settled sewage and the mixture applied to the filter. Average results for a filter loading of 200 to 248 gal. per day per cu. yd. of filter media and a settled sewage B.O.D. of 105 to 175 p.p.m. were as follows: final effluent B.O.D.—9 to 17 p.p.m.; nitrate in final effluent—3 to 16 p.p.m. as N. A noteworthy feature of the process was that the final effluent contained a smaller concentration of nitrate than did the effluent from a plant not employing recirculation.

Another process studied was that of alternating double filtration. Under the conditions of one experiment the results obtained by alternating double filtration were better than those from the process of recirculation of a volume of effluent equal to that of the settled sewage.

Another recent advance in biological filtration has been the development of the covered, aerated filter. In this type of filter the top is completely closed and air is supplied to the filter by a fan. Several experiments have been made in which the performance of full-scale covered, aerated filters has been compared with that of open filters treating similar settled sewage. The experiments covered periods ranging from 42 to 156 weeks and an abstract of the results is as follows:

Kind of Filter and Depth of Media	Rate of Treatment —Gal. per Cu. Yd. Media per Day	Settled Effluent (p.p.m.)	
		B.O.D.	Nitrate as N
Open, 5 ft. 7½ in.	49	43	14
Closed, aerated, 15 ft.	119	42	9
Open, 7 ft. 6 in.	77	12	51
Closed, aerated, 13 ft. 6 in.	165	25	31
Open, 6 ft.	103	54*	8
Closed, aerated, 12 ft.	221	46*	7
Open 7 ft. 6 in.	116	72	3
Closed, aerated, 18 ft.	234	38	1
Open 7 ft. 6 in.	127	35	4
Closed, aerated, 18 ft.	280 (approx.)	24	2

* Filtered through paper.

The B.O.D. values of the settled sewage applied to the filters are not given. However, oxygen absorbed values ($KMnO_4$, 4 hours) vary from 84 to 170 p.p.m. and efficiencies in reduction of oxygen absorbed values vary from roughly 50 to 90 per cent. Oxygen absorbed and B.O.D. values are, apparently, approximately comparable.

Several theories, none entirely satisfactory, have been advanced to explain to the greater efficiency of the closed, aerated filter over the open filter. These include more nearly constant temperature in the closed filter, quick removal of carbon dioxide, and larger number of insect larvae.

On the other hand, experiments conducted in South Africa, while not yet completely reported, indicate that if the filters are not overloaded, the performance of covered and uncovered filters is about the same. When overloaded, however, the open filters pond more readily. Those conducting these experiments attribute the high efficiency of both the closed and open filters tested to the fact that they are deeper than filters of ordinary design.

The author concludes that the whole field of biological waste treatment has reached an interesting stage and that what is needed is a continuation of experimental work. Five tables. Thirteen references.

PAUL D. HANEY

Industrial Wastes—Results of Operation of Small-Scale Diffusion Batteries With and Without Reuse of Process Water. By T. W. Brandon, *International Sugar Journal*, **49**, 154–156 (1947).

Experiments to determine whether the reuse of process waters, normally wastes of high pollution characteristics, adversely affects the quality of the diffusion juices in the beet sugar manufacture were made at the Peterborough beet sugar factory by the Water Pollution Research Laboratory for the British Sugar Corporation. To avoid differences of beet composition, factory layouts, etc., two small-scale diffusion batteries were operated in parallel using fresh water and return process water, respectively.

Each battery comprised eight cells, a cell having the capacity of about four liters and holding about 2 kilograms of cossettes. The batteries were equipped to simulate conditions of full plant scale, were charged with freshly cut cossettes from the same chute and were operated under the same conditions conforming generally to full plant-scale procedure. Of four experiments, No. 1 and 2 and No. 3 and 4, respectively, were identical in detail. The use of fresh water and return water were alternated in the batteries for like experiments and the results for these were averaged to compensate for slight inequalities of construction.

Samples were collected at regular intervals (each 2 hours for experiments 1 and 2 and each 1.75 hours for experiments 3 and 4) of raw juice, battery supply water, pulp press water, exhausted slices and pressed pulp. Determinations comprised sucrose content (in all samples), density (of raw juice), pH (of battery supply and pulp press water), total weight (of exhausted slices and pressed pulp), and at 4.0-hr. and 3.5-hr. intervals, respectively, of dry substance in pressed pulp.

During experiments 3 and 4, samples of diffusion juices were subjected to first stage carbonization including filtration under vacuum in the laboratory. Also examples of experiment 3 which had been carbonated to the first stage were further carbonated to the second stage and vacuum filtered.

The pressability of spent pulp from the experiments was determined, subjecting it to pressures of 200 to 250 lb. per sq. in. for approximately five minutes.

The following conclusions, substantiated by tabulized data, were made:

1. The diffusion juice from a return water battery had a density and purity generally similar to that from a fresh water battery and, further, these values were comparable to those obtained in the factory processing of the Peterborough plant.
2. The use of return water in a battery had no adverse effect on the purity or other characteristics of the carbonated juice.
3. The use of return water did not adversely affect the proportion of sucrose in the juice or in the pressed pulp.
4. The spent pulp from a return water battery was more easily pressed than that from a fresh water battery, and the lower the pH of the return water supplying the battery, the greater was the portion of dry substance in the pressed pulp for a given degree of pressing.

Bruce M. McDill

Industrial Wastes—Waste Waters from Beet Sugar Factories, Their Treatment and Disposal. By T. W. Brandon. *International Sugar Journal*, **49**, 98–100 and 124–126 (1947).

An increase in beet sugar production in Great Britain between 1922–23 and 1938–39 from 7,000 to about 500,000 tons, with the large volumes of wastes of high-polluting characteristics incident thereto, and by reason of the various methods of waste reuse and waste disposal practiced at some 18 factories in the country, resulted in the examination of methods of waste treatment at four factories chosen so as to include most of the methods now in use. The studies were made during the 1944–45 campaign by the Water Pollution Research Laboratory at the request of the British Sugar Corporation.

The average factory processes approximately 2,000 tons per day during a campaign of about 100 days. The volume of untreated waste water may be as high as 5,000 gal. per ton of beets. Four types of wastes of markedly different characteristics are produced (Table 1).

TABLE 1.—Volume and Biochemical Oxygen Demand (B.O.D.) of Waste Waters from Manufacture of Beet Sugar

Waste Water	Volume (Gal. per Ton of Beet Processed)	B.O.D. (5-Day 18.3° C.) P.P.M.
Transport water	1,900–3,500	200
Process water	300–615	1,000–1,500
Drainings from lime sludge	40–80	1,500–2,000
Condenser water	1,000–3,500	30–50

These data indicate an estimated population equivalent of untreated mixed wastes of about 240,000 for a 2,000 ton plant.

Transport Water. The sedimentation and reuse of transport water for fluming beets presented no serious difficulty; factories used this method successfully. Devices at each of the four factories examined comprised Hirschfelder tank and pond, Borzig tank, or lagoons. Except for one installation where soil conditions were unusual and the sedimentation period (Borzig tank) was short, the average reduction in suspended solids averaged between 92 and 98 per cent. Hirschfelder and Borzig tanks produced sludge containing 260,000 to 280,000 p.p.m. total solids. This sludge was discharged to lagoons.

Experiments of aiding the clarification of transport water by chemical coagulation resulted in some improvement but suggested that the additional cost was not justified.

Process Water. Suggested methods of treatment of this waste by (a) chemical coagulation, (b) biological processes similar to those used for domestic sewage and (c) controlled fermentation, reduce the polluting character of the waste between 50 per cent (for chemical methods) and 80 per cent (for certain biological processes), but these effluents can not be discharged to most streams in this country without causing serious nuisance. A large portion of process water is now reused by most factories, including the four studied.

At two of the factories examined, the process water was recirculated quickly through a small system provided with efficient screening. Suspended matter in the return water was not excessive. These factories operated throughout the campaign without discharging any of this waste. The other two, provided with larger systems and with less efficient screens, were forced to discharge portions of the process water. From one plant the discharge averaged 100,000 g.p.d. of liquid containing 1.1 per cent sucrose and having a B.O.D. of about 4,000 p.p.m. The conclusion reached as a result of the investigation was that properly designed equipment for a short period recirculation and for effective screening will permit continuous reuse of process water without any discharge to the receiving stream.

Drainage from Lime Sludge. Lime sludge (50 per cent moisture) from the diffusion juice carbonization process rather generally is watered to flush the material to ponds. Drainage from these ponds has high pollution value which depending somewhat on the characteristics of waste, or water used for flushing purposes. Since sludge removed from ponds at the end of the campaign for agricultural use also has a water content of about 50 per cent, it is evident that the pollution factor is the water added for flushing. It is concluded that arrangements may well be made at factories to handle sludge direct from carbonization processes and thereby avoid an objectionable waste.

Condenser Water. Methods of treatment and disposal of condenser waters (comprising, partly, cooling water from seal tanks for barometric condensers, partly condensate from evaporators and vacuum pans, and sometimes partly cooling waters from pulp driers and oil turbine coolers) varied from cooling in an atmospheric cooling tower and pond in series with chlorination and reuse in the factory to inadequate cooling-pond systems and admixture with other wastes requiring discharges to the receiving stream. This water, though relatively low in oxygen demanding material, has such volume that at one plant it reached a population equivalent of 12,000.

Adequate cooling, chlorination, and reuse in the factory for processing or for recirculating in the condenser system showed that no serious difficulties are involved and offered the most promising method of disposal. Chlorination is essential to repress fungus growths. Liquid remaining in the system at the end of the campaign can probably be discharged or

can be used for dilution of other ponded excess wastes in preparation for biological treatment.

Treatment by Biological Filtration. This study indicates that reuses of waste waters and elimination of lime drainage will reduce the waste problem about 90 per cent. Experimentation using a percolating filter 12.0 ft. in dia. by 6.0-ft. deep as a pilot plant proved the practicability of the modification of ponded excess wastes. During the study polluting characteristics of lagooned liquid gradually decreased with storage so that the rate of filter application could be gradually increased from 60 gal. per cu. yd. per day of waste diluted with river water to 300 gal. per cu. yd. per day (applied without dilution), obtaining an effluent with B.O.D. content of 20 p.p.m. It is estimated that a single percolating trickling filter unit 60.0 ft. in dia. by 6.0-ft. deep operated continuously throughout the year would be capable of modifying residual wastes at a factory processing 2,000 tons of beets per day. It follows that, by recirculation and reuse of waste waters and by treatment of residual or excess wastes using biological filtration, discharge of polluting water from beet sugar factories may be prevented.

BRUCE M. MCDILL

Recent Developments in the Microbiology of Retting. Part II—The part played by bacteria in retting the flax and in purifying the liquor. *Jr. Soc. of Chemical Ind.,* Trans. and Communications, V. 65, pp. 373–376 (1946).

Bacteria causing soft rot of potato were found to occur consistently in retting liquor since the soft rot and retting of flax are both due to the decomposition of the pectic complex in the middle lamella. The number of these organisms increase considerably during retting.

Both soft rot and flax retting were also produced by an enzyme preparation of *B. subtiles* in the absence of the cells or their growth. The organisms causing both the soft rot and retting of flax were mainly spore forming anaerobes and to a smaller extent spore forming aerobes. The anaerobic spore forming organisms were classified as strains of *Clostridum tertium.*

It was found that bacteria in an infusion of flax under quiescent conditions resulted in the formation of acidic liquor. In a similar infusion, but kept aerobic by a current of air, the liquid tended to become alkaline with much less volatile acid content. Aeration also decreased the polluting strength of the liquor to much greater extent than under quiescent conditions. With continuous aeration during flax retting the liquor can be reused for subsequent batches of flax. Such a practice cannot be accomplished under quiescent conditions because the acidic products of metabolism tend to inhibit the growth of bacteria when the liquor is reused.

H. HEUKELEKIAN

River Pollution: Effects of Chemical Works on Fisheries. ANON. *The Chemical Age,* 62, 1470, 353–354 (Sept. 13, 1947).

This is an abstract of a British Field Sports Society report on the pollution of English salmon rivers. It records the gradual destruction of salmon fisheries by industrial waste and domestic sewage over the past 40 years. It lists the volumes of wastes discharged into all important streams and coastal waters, and estimates the annual reduction of the salmon catch.

It is pointed out that many industries have made a sincere effort to reduce their pollution load, but that most are indifferent. Also, many of the sewage treatment plants are out-dated and over-loaded, but very large volumes of sewage are discharged from communities with no treatment works.

The article concludes with a list of treatment suggestions for specific wastes, but these are necessarily fragmentary.

RICHARD D. HOAK

Slaughterhouse Waste Treatment Guide. WEST VIRGINIA WATER COMMISSION. 20 pp. (November 15, 1946).

Terms encountered in slaughterhouse waste treatment are defined for the benefit of industrial representatives. Results of studies in six other states are briefly described, including outlines of several packing plant waste treatment plants.

A table lists results of flow measurements and analyses at four small West Virginia slaughterhouses, two with treatment and two without. Results at one plant killing 25 hog-units daily are interesting because of the results obtained with septic tank treatment, although sizes of the treatment units and details of the survey or collection of test samples are not given. Meat scraps are rendered but blood is included in the wastes. The treatment unit consists of three parallel septic tanks and a filter; whether sand or rock filter is not noted. A partial tabulation of results is as follows:

Analysis	Raw Waste (p.p.m.)	Septic Tank Effluent (p.p.m.)	Final Effluent (p.p.m.)
B.O.D.	21,810	980	240
Total nitrogen	5,420	256	130
Suspended solids, total	12,160	182	63

Methods for reducing wastes in small slaughterhouses (less than 40 hog-units capacity) which may eliminate the need for treatment are outlined. Where some treatment is necessary, units such as settling or septic tanks, dry wells, etc., are recommended and described.

Standard and high-rate trickling filters are suggested for larger plants and computations of design for each system are given. Layout and elevational sketches are included.

W. A. HASFURTHER

Fats and Waxes from Sewage. ANON. *Chem. Trade J.*, **121**, 321–322 (Sept. 26, 1947).

About 4/5 of the wool processed in England (about 1/5 of the world total) is handled by the Bradford, Yorkshire, wool-combining industry, and the greater proportion of the wool-scouring liquor passes directly to the sewers. The sewage arriving at the sewage works averages about 640 p.p.m. of grease in a highly emulsified state. The grease is precipitated with the sewage sludge by sulfuric acid, following a procedure adopted many years ago.

After treatment to remove detritus, the sewage passes to precipitation tanks where the acid is added. The effluent from these tanks is oxidized on biological filters. These filters cover an area of 53 acres, and are among the largest in the world. The filter medium is hard Yorkshire coal.

The sludge from the acid tanks, plus the detritus, is pretreated with sulfuric acid and hot-pressed in plate and frame filter presses. There are 128 of these, each consisting of 46 plates 36 in. square. The cakes are allowed to mature, when biological action reduces the grease content, then ground and sold for fertilizer compounding. From 20,000 to 30,000 tons are sold for this purpose annually.

Grease is separated from the filter effluent by flotation, and this raw material is clarified in the grease house. Clarification is effected by treatment with sulfuric acid (5 per cent by weight) and boiling with live steam for 3 hours. The crude product is about 70 per cent wool grease, and the balance is of domestic origin. It is dark brown and has an unpleasant odor, but it has a uniform composition. Most of it has been sold to distilleries.

In 1935, the Bradford Corporation engaged a grease research chemist. This move resulted in the production of deodorized and bleached grades of grease. A rust preventive was made, in 1940, by converting the free fatty acids associated with the lanolin into magnesium soaps. Axle grease has been made (Crujol) by saponification of the grease with powdered caustic soda. The unsaponifiable matter in Crujol is recovered by solvent extraction to yield a viscous brown oil called Varwolax, and a powdered soap called Serojol. The latter is used as a source of fatty acids by splitting with sulfuric acid. The former has found application in the paint trade.

A handbook dealing with the engineering and chemical aspects of the work may be obtained from W. H. Hillier, Esholt Hall, near Shipley, Yorkshire, England; price, 5 shillings.

RICHARD D. HOAK

Refinery Waste Disposal—XIX. Modifications of Oil-Water Separators to Meet Specialized Applications. BY W. B. HART. *Petroleum Processing*, **2**, 632–639 (Aug. 1947).

The oil-water separator described in preceding articles is the most modern equipment of its kind, but under some conditions a lower degree of treatment may be satisfactory, or a waste may be more readily settleable.

Where a refinery produces light products (40° API or lighter) a simple separator may be effective, because these oils rise rapidly, do not emulsify readily, and chemical treatment is not usual in their manufacture. In such instances, a rectangular basin with a waste distribution section, but without a film rupture chamber, will serve very well. The basin should have a device for removing the floated oil and a travelling suction pump for removal of sediment; where sediment volume is small, a single portable pump may be used for several basins. If a higher degree of cleanup is necessary, the basin may be provided with a redistribution baffle, thereby dividing it into primary and secondary sections. Where finished products are packaged, stored, or moved, only runoff water may require treatment. Here there will rarely be emulsions, but silt, sand, and cinders will be present, and separation may be effected in a single basin with a primary zone for solids removal separated from a secondary zone by a double baffle; oil can then be recovered in the secondary section.

It is important that careful consideration be given all conditions before deciding that a complete separator is not required. Too often wishful thinking has prompted the installation of an improper separator, and the device is then condemned because it will not yield a suitable effluent. Complete separators have also been condemned, usually because an inadequate survey (or none) has been made, and in such cases effluents have been unsatisfactory.

Separators, once installed, cannot be forgotten; they need proper maintenance and continued attention to operation. Worn, broken, or corroded parts must be replaced promptly, particularly must the knife-edges of weirs be kept clean and level. Film rupture chamber packing must be cleaned rather frequently; careful "rubbing" of the packing will often suffice, but if the chamber tend to plug, the packing must be removed for cleaning. A schedule for lubrication and inspection is desirable to insure that bottom scrapers and pump lines are in good condition.

Separator operation should be based on constant availability of design capacity. If settleable matter is allowed to build up on the bottom, the cross-sectional area will be reduced and flow rate and turbulence will increase, resulting in poor separation. Bacterial action in bottom sludge will evolve gases that will interfere with operation. Flight scrapers should be operated often enough to keep bottom sludge at a minimum; usually twice each 8-hour shift will suffice.

A false idea is prevalent that an oil layer held on the water surface will increase separator efficiency. In a properly designed and operated separator, oil globules that reach the surface will stay there with no help from an oil layer; also, evaporation from such an oil layer may create a serious fire hazard, for losses up to 30 per cent have been observed. Separators have sometimes been covered to eliminate fire hazard, but such practice converts the separator into a bomb; ignition of the right air-vapor mixture could cause a terrific explosion. Best practice is to leave the separator open and keep the surface reasonably free from oil.

Separators should, wherever possible, be operated on a 24-hour basis. This should be done not only because of their operational requirements, but because they serve as a good indicator of abnormal conditions in the refinery. Also, separators are not designed for great oil storage capacity. If a break occurs and constant attention is lacking, the facilities will be overtaxed and oil will be lost to surface water.

Where a waste treatment problem occurs at a refinery there is a tendency to decide that an oil-water separator will solve the problem. No separator that operates by gravity is a panacea for all pollution ills. Where heavy oils must be separated, the difference in gravity between oil and water becomes very important; at gravities below 18° API, the separator length increases very rapidly for effective separation. For such heavy oils other methods of separation should be considered.

Separator operation is limited by stable oil-water emulsions, where water is the continuous phase. These emulsions mix

with water in all proportions, and the emulsion will not break naturally even after years of storage. Special treatment must be employed to break them.

Suspended matter also may limit separator operation. With fine particles, where the surface/volume ratio is high, an oil coating may be of such a character that the settling tendency of the particle may just neutralize the tendency of the oil to rise, and the particles plus their oil layer will eventually pass out with the separator effluent. Those cases where the oil carries the particle to the surface, or the particle carries the oil to the bottom, are obviously beneficial.

Where bottom sediment captures large amounts of oil, the oil will not disengage itself from the silt and rise. In some cases as much as a barrel of oil may be trapped by a cubic yard of sediment. Sludge of this kind must be handled with care, and usually the oil must be separated from the silt for reasons of economy, and to avoid water pollution from the silt dump. Cone-bottom tanks, with oil skimmers and compressed air for agitation, have been used to separate oil from silt. But even the washed silt may retain some oil and it should be used for fill to permit bacterial action to destroy the residual oil.

RICHARD D. HOAK

Random Reflections on Sewage Purification. BY JOHN HURLEY. *The Surveyor,* **106**, 655–658 (Dec. 19, 1947).

Sewage treatment is recognized as an essential service, and, of all municipal services, is motivated by most unselfish motives. Other services are provided for the benefit of the local tax payer; sewage treatment is provided for the benefit of the inhabitants of communities further down the stream. In some instances local residents may be bothered by flies and odors from the works, and would be better off were a plant not provided.

An argument of this kind leads naturally to regionalization in sewage disposal. "It can be said that there seems no immediate prospect of comprehensive centralization or regionalization of sewage disposal." There have been proposals of the organization of districts for sewage treatment taking in entire drainage areas. Organizations on such a scale would not necessarily contemplate a single works for the entire area. It would appear at the present time that perhaps the formation of joint sewage boards to serve two or more neighboring municipalities would be more in order.

In some cases there would accrue great advantage with combined supervision. This would be particularly true in case a large competent staff of a large works could advise and consult in the operation of small outlying works. Bringing the sewage to a single point for treatment might entail too great expense for sewers.

Regarding pollution of streams and the work of the Rivers Boards it appears that there is a wide variation in what is accomplished in pollution prevention. At present there are some 1,600 authorities which share the responsibility for pollution prevention. Those making the attempt to do the work find it difficult, as the present law is none too helpful. The Rivers Board Bill to be pushed during this session of Parliament will be welcomed by those concerned with condition of the streams. "These 29 boards will have very comprehensive functions, covering in addition to pollution prevention, the work now done by Catchment Boards and Fishery Boards, plus certain other responsibilities in special cases. Their boundaries will be delineated by drainage areas, not by artificially drawn lines such as county or borough boundaries."

The formation of rivers boards, with the whole of a watershed under the control of a single authority, should be very helpful. A strong board in charge of a river should serve as much a protection to an efficient sewage works as it would a scourge to the works not producing the best possible effluent.

T. L. HERRICK

U. S. and Canadian Member Associations of the Federation of Sewage Works Associations.

ASSOCIATIONS SHOWN ON MAP

1. Arizona Sewage and Water Works Assn.
2. California Sewage Works Assn.
3. Central States Sewage Works Assn.
4. Dakota Water & Sewage Works Conf.
   North Dakota Section
   South Dakota Section
5. Florida Sewage Works Assn.
6. Georgia Water & Sewage Assn.
7. Iowa Sewage Works Assn.
8. Kansas Sewage Works Assn.
9. Maryland-Delaware Water & Sewerage Assn.
10. Michigan Sewage Works Assn.
11. Missouri Water & Sewerage Conf.
12. Montana Sewage Works Assn.
13. New England Sewage Works Assn.
14. New Jersey Sewage Works Assn.
15. New York State Sewage Works Assn.
16. North Carolina Sewage Works Assn.
17. Ohio Conference on Sewage Treatment
18. Oklahoma Water & Sewage Conf.
19. Pacific Northwest Sewage Works Assn.
20. Rocky Mountain Sewage Works Assn.
21. Texas Sewage Works Section
22. Pennsylvania Sewage & Ind. Wastes Assn.
23. Arkansas Water & Sewage Conf.
24. Kentucky-Tennessee Ind. Wastes & Sewage Works Assn.
25. Virginia Ind. Wastes & Sewage Works Assn.
26. Canadian Inst. on Sewage & Sanitation
27. West Virginia Sewage & Ind. Wastes Assn.

ASSOCIATIONS NOT SHOWN ON MAP

Federal Sewage Research Assn. (Federal employees wherever stationed)
Argentina Society of Engineers, Sanitary Engineering Division
Institution of Sanitary Engineers (England)
Institute of Sewage Purification (England)
Puerto Rico Water and Sewage Assn.
Swiss Assn. of Water & Sewage Professionals

Federation of Sewage Works Associations

1948

Annual Directory

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MEMBERSHIP SUMMARY

DIRECTORY OF MEMBERS

FEDERATION OF SEWAGE WORKS ASSOCIATIONS INC.

325 Illinois Building, Champaign, Ill.

1947–48 OFFICERS

President: George S. Russell

Vice-President: V. M. Ehlers

Treasurer: W. W. DeBerard

Executive Secretary-Editor: W. H. Wisely

Advisory Editor: F. W. Mohlman

PAST PRESIDENTS

Name	*Period Served*
Charles A. Emerson	1928–41
*Arthur S. Bedell	1941–42
George J. Schroepfer	1942–43
A. M. Rawn	1943–44
Albert E. Berry	1944–45
John K. Hoskins	1945–46
Francis S. Friel	1946–47

HONORS AND AWARDS

Honorary Members

The qualifications for Honorary membership in the Federation are set forth in Article II, Section 4 of the By-Laws. Honorary Members are elected upon recommendation by a committee comprising the President and four latest Past Presidents, the senior Past President as chairman, in accordance with a policy adopted by the Board of Control on October 23, 1943. Honorary Members elected to date are as follows:

Charles Alvin Emerson	1941
*Arthur S. Bedell	1942
Julius W. Bugbee	1942
Langdon Pearse	1942
Charles Gilman Hyde	1943
Howard Eugene Moses	1943
Floyd William Mohlman	1944
Willem Rudolfs	1945
William John Orchard	1946

The Harrison Prescott Eddy Medal

The Harrison Prescott Eddy Medal is awarded annually to a member of any Member Association of the Federation "for outstanding research contributing in important degree to the existing knowledge of the fundamental principles or processes of sewage treatment, as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL." The award commemorates Harrison Prescott Eddy, a famous engineer and a pioneer in the art of sewage treatment.

Past recipients of the award are:

Harry Willard Gehm	1943
John Raymond Snell	1944
Lloyd R. Setter	1945
H. Heukelekian	1946
Richard Pomeroy and Fred D. Bowlus	1947

* Deceased.

The George Bradley Gascoigne Medal

The George Bradley Gascoigne Medal is awarded annually to a member of any Member Association of the Federation "for outstanding contribution to the art of sewage treatment works operation through the successful solution of important and complicated operational problems, as comprehensively described and published during any stated year in SEWAGE WORKS JOURNAL." This award is in memory of George Bradley Gascoigne, a prominent consultant from 1922 to 1940, who demonstrated an unusual interest in matters of sewage works operation.

Past recipients of this award are:

Kerwin L. Mick	1943
James T. Lynch and Uhl T. Mann	1944
John D. McDonald	1945
LeRoy Winfield Van Kleeck	1946
Leon S. Kraus	1947

The Charles Alvin Emerson Medal

The Charles Alvin Emerson Medal is awarded annually to a member of any Member Association of the Federation "for outstanding service in the sewerage and sewage treatment works field, as related particularly to the problems and activities of the Federation of Sewage Works Associations in such terms as the stimulation of membership, improving standards of operational accomplishments, fostering fundamental research, etc." This award honors Charles Alvin Emerson, who served as President of the Federation from 1928 to 1941 and holds the distinction of being its first Honorary Member.

Past recipients are:

Floyd William Mohlman	1943
Willem Rudolfs	1944
Harold Warner Streeter	1945
F. Wellington Gilcreas	1946
Langdon Pearse	1947

The Kenneth Allen Award

Each Member Association of the Federation is privileged once in each three years to designate one of its members to receive the Kenneth Allen Award "for outstanding service in the sewage works field, as related particularly to the problems and activities of any Member Association." The award commemorates Kenneth Allen, an eminent engineer who made notable contributions to the creation of the Federation and the New York State Sewage Works Association.

Recipients of this award have been:

1943

Name	*Member Association*
Harry Thornton Calvert	I. S. P. (England)
Edward F. Eldridge	Michigan
John Kurtz Hoskins	Federal
Fred Merryfield	Pacific Northwest
Edward P. Molitor	New Jersey
Robert S. Phillips	North Carolina
Alfred Henry Weiters	Iowa
William Homer Wisely	Central States

1944

Name	*Member Association*
Alfred Edward Berry	Canadian
Van Porter Enloe	Georgia
Albert Legrand Genter	Maryland-Delaware
F. Wellington Gilcreas	New England
Charles A. Holmquist	New York
Dana Ewart Kepner	Rocky Mountain
Leon Benedict Reynolds	California
Wilson Waldo Towne	Dakota

1945

Name	*Member Association*
Howard Eugene Moses	Pennsylvania
George S. Russell	Missouri
Dario Travaini	Arizona
Frederick Holman Waring	Ohio
Joe Williamson, Jr.	Florida
Murray Alderson Wilson	Kansas

1946

Name	*Member Association*
E. J. M. Berg	Texas
Frank E. DeMartini	Federal
John R. Downes	New Jersey
Thomas J. Doyle	Michigan
John Henry Garner	I. S. P. (England)
Harold Benedict Gotaas	North Carolina
William P. Hughes	Pacific Northwest
Theodore R. Lovell	Iowa
George Martin	Central States

1947

Name	*Member Association*
William T. Knowlton	California
Floyd W. Pinney	Dakota
Gilbert R. Frith	Georgia
Clarence E. Keefer	Maryland-Delaware
Stuart E. Coburn	New England
Wellington Donaldson	New York
Henry J. Darcey	Oklahoma
Carroll H. Coberley	Rocky Mountain
William Storrie	Canadian Institute
William Merriam Cobleigh	Montana

The William D. Hatfield Award

The William D. Hatfield Award recognizes outstanding annual sewage works operation reports. Following the 1946 award, the Board of Control authorized identical awards for outstanding annual reports prepared (1) for plants serving less than 10,000 population, (2) for plants serving populations of 10,000 to 100,000, and (3) for plants serving populations of more than 100,000 persons.

Recipients of this award have been:

1946

Walter M. Kunsch

1947

Name	*Plant Population Classification*
F. E. Peterson	Under 10,000
John R. Szymanski	10,000 to 100,000
Warren H. Sleeger and George J. Schroepfer	Over 100,000

Membership Prizes

Prizes for membership activity in its various Member Associations have been awarded by the Federation since 1943. The following Member Associations have received these prizes:

Association	*Year*
Federal Sewage Research Assn. and Central States Sewage Works Assn.	1943
Missouri Water and Sewerage Conf. and Central States Sewage Works Assn.	1944
Arizona Sewage and Water Works Assn. and Canadian Institute on Sewage and Sanitation	1945
Oklahoma Water and Sewage Conf. and Canadian Institute on Sewage and Sanitation	1946
Institute of Sewage Purification (Eng.) and Arkansas Water and Sewage Conference	1947

Quarter Century Operators Club

The Quarter Century Operators Club is an informal group comprising Active or Corporate Members of any Member Association who had been engaged in sewage treatment works operation, on a full-time resident basis, twenty-five years prior to the date of their admission into the Club. The Club was created in 1941 under the sponsorship of Frank Woodbury Jones, who serves as its registrar. The roster:

Charles C. Agar
Reuben A. Anderson
Harry M. Beaumont
George C. Behnke
Julius W. Bugbee
Raymond G. Case
E. Sherman Chase
Stuart E. Coburn
Morris M. Cohn
Earl Devendorf
John R. Downes
Almon L. Fales
Arnold H. Goodman
Wm. C. Hamm
Charles C. Hommon
Frank W. Jones
Roy S. Lanphear
John V. Lewis
C. D. McGuire
Arthur H. Niles
I. H. Nevitt
Wm. M. Piatt
Wm. A. Ryan
Theodore C. Schaetzle
Glenn Searls
John S. Simmerman
H. W. Streeter
S. L. Tolman

ANNUAL MEETINGS AND CONVENTIONS

Annual Meeting Number	*Location*	*Date*
1	Chicago, Illinois *	October 16, 1928
2	New York, New York *	January 18, 1929
3	New York, New York *	January 14, 1930
4	New York, New York *	January 22, 1931
5	New York, New York *	January 22, 1932
6	New York, New York *	January 19, 1933
7	New York, New York *	January 18, 1934
8	New York, New York *	January 18, 1935
9	New York, New York *	January 16, 1936
10	New York, New York *	January 22, 1937
11	New York, New York *	January 21, 1938
12	New York, New York *	January 20, 1939
13	New York, New York *	January 18, 1940
	Chicago, Illinois †	October 3–5, 1940
14	New York, New York *	January 15, 1941
	New York, New York †	October 9–11, 1941
15	Cleveland, Ohio ‡	October 22–24, 1942
16	Chicago, Illinois ‡	October 21–23, 1943
17	Pittsburgh, Pa. ‡	October 12–14, 1944
18	Chicago, Illinois *	October 17–18, 1945
19	Toronto, Ont., Can. ‡	October 7–9, 1946
20	Philadelphia, Pa.*	Oct. 10, 1947
	San Francisco, Calif. †	July 21–24, 1947

DIRECTORY OF COMMITTEES

1947–48

Constitutional Committees

(*See Article VI of By-Laws*)

EXECUTIVE COMMITTEE OF THE BOARD OF CONTROL

George S. Russell, *Chairman*

A. E. Paxton
L. D. Matter
F. S. Friel
Frank S. Taylor
John L. Strelow
V. M. Ehlers

GENERAL POLICY COMMITTEE

The General Policy Committee studies and recommends to the Board of Control upon all matters of policy affecting the well-being and usefulness of the Federation and its Member Associations; matters of public relations; the advancement of and the professional and social status of members, and such other matters of similar nature as may be referred to it by the Board.

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* Annual business meeting of Board of Control.

† Convention of membership-at-large.

‡ Annual business meeting of Board of Control and convention of membership-at-large.

F. S. Friel, *Chairman*

A. H. Niles
John R. Downes
Dana E. Kepner
R. E. Fuhrman
Kenneth Chrysler
Henry M. Rath

Publications Committee

The Publications Committee arranges the technical programs for the annual conventions of the Federation and has general supervision of all publications of the Federation.

C. C. Larson, *Chairman*

Rolf Eliassen
F. W. Gilcreas
Carl E. Green
Harry J. Krum
F. W. Mohlman
W. H. Wisely

Organization Committee

The Organization Committee examines and reports to the Board on applications for membership in the Federation and endeavors to encourage the formation of new regional associations or conferences eligible for membership.

Earnest Boyce, *Chairman*

C. R. Compton
R. H. Suttie

Sewage Works Practice Committee

The Sewage Works Practice Committee reviews and directs for publication any resolution, report or publication which establishes professional or technical standards in the name of the Federation.

Morris M. Cohn, *Chairman*

Norval E. Anderson
D. E. Bloodgood
R. F. Brown
G. P. Edwards
F. W. Gilcreas
K. V. Hill
John W. Hood
C. E. Keefer
C. W. Klassen
L. W. Van Kleeck
Kerwin L. Mick
F. W. Mohlman
A. H. Niles
Langdon Pearse
Willem Rudolfs
F. M. Veatch
W. H. Wisely

Subcommittee on Use of Sludge as Fertilizer

This subcommittee of the Sewage Works Practice Committee was assigned to compile a manual of practice on "Utilization of Sewage Sludge as Fertilizer." The assignment has been completed and Manual of Practice No. 2 was published under the above title in November, 1946.

A. H. Niles, *Co-Chairman*

Langdon Pearse, *Co-Chairman*

F. W. Gilcreas
F. W. Mohlman
Willem Rudolfs
T. C. Schaetzle
L. W. Van Kleeck
W. H. Wisely

Subcommittee on Occupational Hazards

This subcommittee of the Sewage Works Practice Committee has been assigned to compile a Manual of Practice on "Occupational Hazards in the Operation of Sewage Works." The manual has been completed and was distributed to the membership in December, 1944.

L. W. Van Kleeck, *Chairman*

S. H. Ash
Reuben F. Brown
Joseph Doman
Fred R. Ingram
L. L. Langford
L. E. West

Subcommittee on Air Diffusion

This subcommittee of the Sewage Works Practice Committee has been charged with the duty of producing a Manual of Practice on "Air Diffusion in Sewage Treatment." The manual is in preparation.

Norval E. Anderson, *Chairman*

A. J. Beck
G. P. Edwards
C. T. Mickle
W. F. Schade
C. B. Townend

Subcommittee on Sewer Maintenance

This subcommittee of the Sewage Works Practice Committee has been directed to develop a Manual of Practice on "Maintenance of Sewers and Appurtenant Structures." The manual is in an early stage of preparation.

R. F. Brown, *Chairman*

Thos. B. Garry
W. H. Brown, Jr.
G. E. Fink
Grant Olewiler
R. L. Patterson
Henry Fitch
B. H. Grout
Roy E. Phillips
Richard Pomeroy
Robert P. Shea
John H. Brooks, Jr.
Forest Weber

Subcommittee on Chlorination of Sewage

This subcommittee of the Sewage Works Practice Committee has been assigned the development of a Manual of Practice on "The Use of Chlorine in Sewage Treatment." The manual is in a late stage of preparation.

F. W. Gilcreas, *Chairman*

N. S. Chamberlain
A. E. Griffin
H. A. Faber

Subcommittee on Standardization of Units

This subcommittee of the Sewage Works Practice Committee has been assigned to develop an approved schedule of units to be used in the reporting of plant operation and laboratory data. A committee of about forty members is at work.

Willem Rudolfs, *Chairman*

Subcommittee on Trickling Filters

This subcommittee of the Sewage Works Practice Committee is engaged in the development of a Manual of Practice to be entitled "Trickling Filters—Their Characteristics and Loadings."

Kenneth V. Hill, *Chairman*

B. F. Hatch
W. S. Mahlie
Wm. E. Stanley

Subcommittee on Sewer Ordinances

This subcommittee of the Sewage Works Practice Committee has been assigned the preparation of a Manual of Practice concerning the regulation and control of the usage of public sewers. The second draft of the manual is under review.

D. E. Bloodgood, *Chairman*

H. E. Babbitt
Fred J. Biele
R. F. Brown
M. M. Cohn
Charles A. Davis
C. E. Keefer
A. F. Lehman
A. H. Niles
B. A. Poole
J. L. Quinn
C. L. Siebert

Subcommittee on Sewage Works Accounting

This sewage works practice subcommittee was created in 1946 for the purpose of developing a manual of practice on accounting procedures for municipal sewage works functions. A preliminary draft of a comprehensive manual on this subject is now being reviewed.

F. M. Veatch, *Chairman*

G. J. Beiswanger
Charles A. Davis
Alfred A. Estrada
E. A. Farmer
Roy E. Ritter
S. I. Zack

Subcommittee on Sanitary Districts

This sewage works practice subcommittee was created in 1946 to develop a manual on the formation and operation of sanitary districts. The subcommittee is now in process of organization.

C. W. Klassen, *Chairman*

Subcommittee on Paints and Protective Coatings

This sewage works practice subcommittee has the function of assembling experience and data on paints and protective coatings used in sewage works, to be presented with recommendations in the form of a manual. The subcommittee was created in 1946 and is now collecting data on this subject.

Kerwin L. Mick, *Chairman*

Virgil Anderson
W. D. Hatfield
J. W. Johnson
W. T. McClenahan
F. W. Pinney
Arthur J. Scanlon
Walter A. Sperry

Research Committee

The Research Committee has the function of stimulating research work among the various Member Associations, and of cooperating with other organizations in the promotion of research.

Willem Rudolfs, *Chairman*

H. E. Babbitt
D. E. Bloodgood
G. P. Edwards
H. A. Faber
A. L. Genter
H. Heukelekian
H. J. Miles
F. W. Mohlman
C. C. Ruehhoft
L. R. Setter
L. W. Van Kleeck

Special Committees

Committee on Awards

The Committee on Awards was created by the Board of Control on October 11, 1941. Functions of the committee are to advise the Board on matters of award procedures and to make recommendations as to the annual winners of the Eddy, Gascoigne and Emerson Awards.

G. M. Ridenour, *Chairman*

Harold B. Gotaas
H. W. Streeter

Honorary Membership Committee

Authorized by the Board of Control on October 24, 1942, this committee comprises the President and four latest, living Past Presidents with the senior Past President as chairman. The committee reviews nominations for election to the grade of Honorary Member and makes recommendations to the Board on such nominations.*

A. M. Rawn, *Chairman*

A. E. Berry
F. S. Friel
J. K. Hoskins
George S. Russell

Finance Advisory Committee

The Finance Advisory Committee was created by the Board of Control on October 11, 1941, and has the duty of advising the Board and officers of the Federation in financial matters.

W. J. Orchard, *Chairman*

F. S. Friel
George S. Russell

Operation Reports Committee

The Operation Reports Committee was created by the Board of Control on October 11, 1941, to provide for Federation recognition of outstanding operation reports. The committee now administers the annual William D. Hatfield Award.

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* See This Journal, 16, 1, 196 (January, 1944).

A. F. Dappert, *Chairman*

Wm. A. Allen
G. A. Hall
Gordon J. Weist

Operator's Qualifications Committee

Authorized by the Board of Control on October 11, 1941, the Operator's Qualifications Committee is assigned to "establish minimal qualifications for operators of various classes of treatment works." The committee also has the duty of collecting and compiling data on present procedures in the licensing and certification of operators, for reference to Member Associations.

L. W. Van Kleeck, *Chairman*

Wm. A. Allen
E. P. Molitor

Industrial Wastes Committee

The Industrial Wastes Committee was created by the Board of Control on October 23, 1943, for the purpose of developing interest in this important field and to direct a program whereby the Federation may be of service in industrial waste problems.

F. W. Mohlman, *Chairman*

D. E. Bloodgood
H. W. Gehm
W. B. Hart
V. L. King
L. F. Oeming
Wm. S. Wise

Nominating Committee

The special Nominating Committee was created by the Board of Control on October 9, 1946, to function in an advisory capacity to the Election Committee. The Nominating Committee is to comprise the last five living Past Presidents, with the senior Past President as chairman.

G. J. Schroepfer, *Chairman*

A. E. Berry
J. K. Hoskins
A. M. Rawn
F. S. Friel

Quarter Century Operators Club Committee

The special Quarter Century Operators Club Committee was created by the Board of Control on October 9, 1946. It is the function of this Committee to establish eligibility requirements, process membership applications, maintain the roster and supervise the activities of the Quarter Century Operators Club.

Frank W. Jones, *Chairman*

Stuart E. Coburn
Harold W. Streeter

Legislative Analysis Committee

The Legislative Analysis Committee was created by the Board of Control on October 17, 1945, to study legislation pertinent to the interests of the Federation and to serve the Board in advisory capacity.

Ralph E. Fuhrman, *Chairman*

Earnest Boyce
V. M. Ehlers
L. J. Fontenelli
David B. Lee
L. D. Matter
L. F. Warrick
R. L. Winget

Constitution and Bylaws Committee

The Constitution and Bylaws Committee was created by the Board of Control on October 10, 1947, to review and develop recommendations for the amendment of the existing Constitution and Bylaws of the Federation.

C. A. Emerson, *Chairman*

F. S. Friel
F. W. Gilcreas
W. J. Orchard
G. S. Russell

Joint Committees With Other Associations

Committee on Standard Methods of Sewage and Industrial Wastes Analysis

Created by the Board of Control on January 22, 1931, the Committee on Standard Methods of Sewage and Industrial Wastes Analysis has functioned with similar committees of the American Water Works Association and American Public Health Association in the production of the laboratory manual *Standard Methods for the Examination of Water and Sewage*. In 1947 the Federation became a joint publisher of this book with the above associations. The committee is presently engaged in a comprehensive research project on analytical methods, which work will continue for at least a year. This project is being financed by a grant made through the National Institute of Health.

W. D. Hatfield, *Chairman*

G. E. Symons
S. E. Coburn
D. E. Bloodgood
A. J. Fischer
F. W. Gilcreas
R. D. Hoak
Keeno Fraschino
W. S. Mahlie
H. Heukelekian
G. P. Edwards
E. W. Moore
M. Starr Nichols
Richard Pomeroy
C. C. Ruchhoft
Willem Rudolfs
R. F. Weston

Committee on Sewage Works Nomenclature

The Committee on Sewage Works Nomenclature was created by the Board of Control on January 22, 1937, to function with similar committees of the American Society of Civil Engineers and American Public Health Association. This Joint Committee on Definition of Terms Used in Sewerage and Sewage Disposal Practice is now engaged in the compilation of a "Glossary of Water and Sewage Control Engineering," in conjunction with the Joint Committee on Definition of Terms Used in Water Works Practice, which comprises the American Society of Civil Engineers, American Public Health Association and American Water Works Association.

C. J. Velz, *Chairman*

C. A. Emerson C. E. Keefer

Committee on Water and Sewage Works Development

The Committee on Water and Sewage Works Development was organized in 1943 to promote the planning of water and sewage works and to encourage the inclusion of such projects in postwar planning programs. The committee, temporarily inactivated, comprises representatives of the Water and Sewage Works Manufacturers Association, American Water Works Association, New England Water Works Association and the Federation of Sewage Works Associations. Federation representatives are:

C. A. Emerson G. J. Schroepfer

Special Convention Committees

Convention Management Committee

The function of this committee is to supervise details of the management of the Annual Meetings of the Federation.

W. J. Orchard, *Chairman*

A. T. Clark W. F. Shephard
A. E. Paxton W. H. Wisely

Meeting Place Committee

This committee reviews invitations received for the Annual Meetings of the Federation and makes recommendations to the Board of Control in regard to the time and place of such meetings.

George S. Russell, *Chairman*

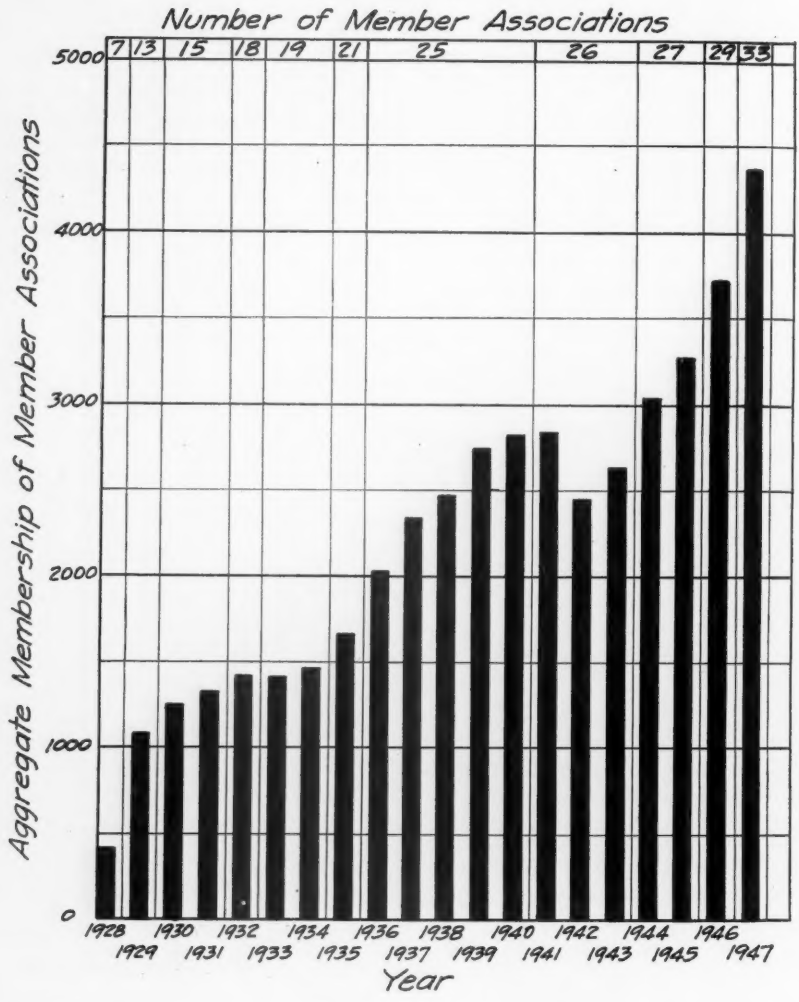
A. T. Clark A. E. Paxton
V. M. Ehlers Daniel J. Saunders
F. S. Friel W. H. Wisely

Publicity and Attendance Committee

The function of this committee is to prepare publicity releases in connection with the Annual Meetings of the Federation and to direct the distribution of such material.

L. H. Enslow, *Chairman*

E. J. Cleary A. Prescott Folwell
M. M. Cohn J. P. Russell
W. S. Foster J. A. Daly



Aggregate Active and Corporate Membership of FSWA Member Associations.

SUMMARY OF MEMBERSHIP

(As at December 31, 1947)

Federation Members

Honorary Members	8
Associate Members	76
Member Associations	33
Active Members	4,307
Alternate Active Members	14
Corporate Members	46

Net Membership of Member Associations *

Member Association	Active	Alternate Active	Corporate	Total
Argentina	—	—	—	—
Arizona	37	—	3	40
Arkansas	33	—	—	33
California	341	2	—	343
Canadian Inst.	346	—	—	346
Central States	554	—	12	566
Dakota	52	—	—	52
Federal	105	—	—	105
Florida	90	—	—	90
Georgia	78	—	—	78
Iowa	82	—	—	82
ISE (Eng.)	34	—	—	34
ISP (Eng.)	188	—	—	188
Kansas	25	—	—	25
Kentucky-Tennessee	45	—	1	46
Maryland-Delaware	40	—	—	40
Michigan	189	7	—	196
Missouri	58	—	—	58
Montana	35	—	4	39
New England	238	—	—	238
New Jersey	108	—	—	108
New York	556	5	3	564
North Carolina	71	—	—	71
Ohio	206	—	2	208
Oklahoma	29	—	—	29
Pacific Northwest	131	—	—	131
Pennsylvania	337	—	12	349
Puerto Rico	36	—	1	37
Rocky Mountain	61	—	—	61
†Switzerland	—	—	—	—
Texas	63	—	—	63
Virginia	69	—	3	72
West Virginia	70	—	5	75
Totals	4,307	14	46	4,367

* Not including Dual Members.
† New Member Association. Admitted to Federation on October 10, 1947.

Directory of Members

MEMBER ASSOCIATIONS

Argentina Society of Engineers, Sanitary Engineering Division (Affiliated 1936).

Territory: Republic of Argentina.
FSWA Contact Member: E. B. Besselievre, Juez Estrada 2840, Buenos Aires, Argentina.

Arizona Sewage and Water Works Association—Sewage Works Section (Affiliated 1928).

Territory: State of Arizona.
President: Harold W. Yost; *First Vice-President:* John Rauscher; *Second Vice-President:* A. A. Frederickson, Jr.; *Director:* A. L. Frick, Jr.; *Secretary-Treasurer:* George W. Marx, c/o Sanitary Engineering Div., Arizona State Dept. of Health, State Capitol Bldg., Phoenix, Arizona.

Arkansas Water and Sewage Conference—Sewage Works Section (Affiliated 1946).

Territory: State of Arkansas.
Chairman: J. R. Pierce; *Vice-Chairman:* Neal B. Thayer; *Director:* F. L. McDonald; *Secretary-Treasurer:* Harrison Hale, 118 Chemistry Bldg., Fayetteville, Ark.

California Sewage Works Association (Affiliated 1928).

Territory: State of California.
President: Harold L. May; *First Vice-President:* Ray L. Derby; *Second Vice-President:* Raymond R. Ribal; *Director:* R. D. Pomeroy; *Secretary-Treasurer:* Lawrence H. Cook, P. O. Box 696, Menlo Park, Calif.

Canadian Institute on Sewage and Sanitation (Affiliated 1933).

Territory: Dominion of Canada.
President: G. H. Richards; *Vice-President:* T. M. S. Kingston; *Director:* R. J. Desmarais; *Secretary-Treasurer:* A. E. Berry, Ontario Dept. of Health, Sanitary Engineering Div., Toronto 8, Ontario, Canada.

Central States Sewage Works Association (Affiliated 1928).

Territory: States of Illinois, Indiana, Wisconsin, and Minnesota.
President: H. G. Rogers; *First Vice-President:* Carl B. Carpenter; *Second Vice-President:* L. S. Kraus; *Third Vice-President:* H. T. Rudgal; *Director:* C. C. Larson; *Secretary-Treasurer:* Paul W. Reed, 1098 W. Michigan St., Indianapolis 7, Ind.

Dakota Water and Sewage Works Conference—Sewage Works Sections (Affiliated 1936).

North Dakota Section

Territory: State of North Dakota.
President: R. J. Lockner; *Vice-President:* George J. Toman; *Director:* Roy G. Spieker; *Secretary-Treasurer:* Jerome H. Svore, c/o State Dept. of Health, Bismarck, N. Dak.

South Dakota Section

Territory: State of South Dakota.
President: Richard V. Curtis; *Vice-President:* Don Wessel; *Director:* Roy G. Spieker; *Secretary-Treasurer:* W. W. Towne; c/o Div. of Sanitary Engineering, State Board of Health, Pierre, S. Dak.

Federal Sewage Research Association (Affiliated 1930).

Territory: Federal employees wherever stationed.
President: Carl E. Schwob; *Vice-President:* R. N. Clark; *Director:* Lawrence M. Fisher; *Secretary-Treasurer:* Ralph C. Graber, c/o USPHS, Room 4122 Federal Security Bldg., So., Washington 25, D. C.

Florida Sewage Works Association (Affiliated 1941).

Territory: State of Florida.
President: Albert L. McGregor; *Vice-President:* J. R. Hoy; *Director:* B. F. Borden; *Secretary-Treasurer:* John G. Patterson, Florida State Board of Health, P. O. Box 210, Jacksonville, Fla.

Georgia Water and Sewage Association (Affiliated 1936).

Territory: State of Georgia.
President: B. L. Coburn; *First Vice-President:* D. H. Hurst; *Second Vice-President:* Clyde Angle; *Director:* H. A. Wyckoff; *Secretary-Treasurer:* V. P. Enloe, R.F.D. No. 5, Box 363, Atlanta, Ga.

Iowa Sewage Works Association (Affiliated 1928).

Territory: State of Iowa.
President: C. O. Alexander; *Vice-President:* Lloyd Heller; *Director:* John L. Strelow; *Secretary-Treasurer:* Leo Holtkamp, E. Ohio St., Webster City, Iowa.

Institution of Sanitary Engineers—England (Affiliated 1932).

Territory: British Empire.
President: Gordon S. McDonald; *Director:* Gordon S. McDonald; *Secretary:* Edward H. Webb, 118 Victoria St., Westminster, S. W. 1, London, England.

Institute of Sewage Purification—England (Affiliated 1932).

Territory: British Empire.
President: F. T. Hambleton; *Director:* W. F. Freeborn; *Federation Contact Member:* J. H. Garner, 28 Aberford Road, Wakefield, Yorks, England.

Kansas Sewage Works Association (Affiliated 1935).

Territory: State of Kansas.
Chairman: Neal Harr; *Vice-Chairman:* Ray E. Lundy; *Director:* P. E. Kaler; *Secretary-Treasurer:* James B. Arbuthnot, c/o State Board of Health, Marvin Hall, University of Kansas, Lawrence, Kan.

Kentucky-Tennessee Industrial Wastes and Sewage Works Association (Affiliated 1946).

Territory: States of Kentucky and Tennessee.
Chairman: Julian R. Fleming; *Vice-Chairman:* L. S. Vance; *Director:* James Ellis; *Secretary-Treasurer:* R. P. Farrell, 420 Sixth Ave., N., Nashville 3, Tenn.

Maryland-Delaware Water and Sewerage Association—Sewage Works Section (Affiliated 1928).

Territory: States of Maryland and Delaware.
President: J. W. Engle; *First Vice-President:* R. C. Willson; *Second Vice-President:* A. A. Bailey; *Director:* R. E. Fuhrman; *Secretary-Treasurer:* Miss E. V. Gipe, c/o State Dept. of Health, 2411 N. Charles St., Baltimore 18, Md.

Michigan Sewage Works Association (Affiliated 1930).

Territory: State of Michigan.
President: T. J. Powers; *Vice-President:* A. T. Kunze; *Director:* W. F. Shephard; *Secretary-Treasurer:* D. M. Pierce, Michigan Dept. of Health, Room 334, Administration Bldg., Lansing 4, Mich.

Missouri Water and Sewerage Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Missouri.
Chairman: Garvin H. Dyer; *Vice-Chairman:* Emmett E. Gamet; *Director:* W. Q. Kehr; *Secretary-Treasurer:* Warren Kramer, c/o State Office Bldg., Jefferson City, Mo.

Montana Sewage Works Association (Affiliated 1944).

Territory: State of Montana.
Chairman: K. Winebrenner; *Vice-Chairman:* F. F. Palmer; *Director:* K. L. Chrysler; *Secretary-Treasurer:* H. B. Foote, Div. of Sanitary Engineering, State Board of Health, Helena, Montana.

New England Sewage Works Association (Affiliated 1929).

Territory: States of Maine, New Hampshire, Vermont, Massachusetts, Connecticut and Rhode Island.
President: LeRoy W. Van Kleeck; *First Vice-President:* Walter H. Brown, Jr.; *Second Vice-President:* Ralph W. Horne; *Director:* L. W. Van Kleeck; *Secretary-Treasurer:* Walter E. Merrill, c/o State Dept. of Health, 511A State House, Boston, Mass.

New Jersey Sewage Works Association (Affiliated 1942).

Territory: State of New Jersey.
President: L. J. Fontenelli; *First Vice-President:* Leslie West; *Second Vice-President:* John Struss; *Director:* P. N. Daniels; *Secretary-Treasurer:* Michael S. Kachorsky, P. O. Box 283, Manville, N. J.

New York State Sewage Works Association (Affiliated 1930).

Territory: State of New York.
President: Edwin C. McKeeman; *Vice-President:* Paul E. Bardet; *Director:* E. J. Smith; *Secretary:* A. F. Dappert, c/o State Dept. of Health, Albany, N. Y.; *Treasurer:* J. C. Brigham.

North Carolina Sewage Works Association (Affiliated 1929).

Territory: State of North Carolina.
Chairman: W. W. Franklin; *Vice-Chairman:* R. W. Luther; *Director:* George S. Rawlins; *Secretary-Treasurer:* G. S. Moore, P. O. Box 125, Albemarle, N. C.

Ohio Conference on Sewage Treatment (Affiliated 1932).

Territory: State of Ohio.
Chairman: L. B. Barnes; *Vice-Chairman:* E. F. Wittmer; *Director:* A. H. Niles; *Secretary-Treasurer:* G. A. Hall, 302 Depts. of State Bldg., Columbus, Ohio.

Oklahoma Water and Sewage Conference—Sewage Works Section (Affiliated 1929).

Territory: State of Oklahoma.
President: R. O. Williams; *Vice-President:* C. E. Moutrey; *Director:* Frank S. Taylor; *Secretary-Treasurer:* H. J. Darcey, State Dept. of Health, Oklahoma City 5, Okla.

Pacific Northwest Sewage Works Association (Affiliated 1933).

Territory: States of Washington, Oregon, and Idaho.
President: H. C. Clare; *First Vice-President:* K. H. Spies; *Second Vice-President:* Emil C. Jensen; *Director:* C. M. Howard; *Secretary-Treasurer:* W. P. Hughes, City Engineer's Office, City Hall, Lewiston, Idaho.

Pennsylvania Sewage and Industrial Wastes Association (Affiliated 1928).

Territory: State of Pennsylvania.
President: N. G. Young; *First Vice-President:* C. H. Young; *Second Vice-President:* E. T. Roetman; *Director:* L. D. Matter; *Secretary-Treasurer:* B. S. Bush, c/o Pennsylvania Dept. of Health, Kirby Health Center, Wilkes-Barre, Pa.

Puerto Rico Water and Sewage Works Association (Affiliated 1947).

Territory: Puerto Rico.
President: Luis Ramos; *Director:* Alberto Hernandez; *Secretary-Treasurer:* Manuel Vinas-Sorba, 1555 Francia St., Santurce, Puerto Rico.

Rocky Mountain Sewage Works Association (Affiliated 1936).

Territory: States of Wyoming, Colorado, and New Mexico.
President: H. G. Watson; *Vice-President:* B. V. Howe; *Director:* W. V. Leonard; *Secretary-Treasurer:* Gerald E. Riepe, 720 Boston Bldg., Denver, Colo.

Swiss Association of Water and Sewage Professionals (Affiliated 1947).

Territory: Switzerland.
President: A. Kropf; *Vice-President:* H. Bachoffner; *Director:* Walter Dardel; *FSWA Contact Member:* Walter Dardel, Aarberg (Berne), Switzerland.

Texas Sewage Works Section (Affiliated 1928).

Territory: State of Texas.
Chairman: J. H. Sorrels; *Vice-Chairman:* Tom Green; *Director:* E. J. M. Berg; *Secretary-Treasurer:* V. M. Ehlers, 501 W. 33rd St., Austin, Tex.; *Assistant Secretary-Treasurer:* Mrs. E. H. Goodwin.

Virginia Industrial Wastes and Sewage Works Association (Affiliated 1947).

Territory: State of Virginia.
President: Reid W. Digges; *Vice-President:* Bryant W. Strother; *Director:* L. L. Hedgepeth; *Secretary-Treasurer:* A. H. Paessler, State Water Control Board, 815 East Franklin St., Richmond 19, Va.

West Virginia Sewage and Industrial Wastes Association (Affiliated 1947).

President: P. D. Simmons; *First Vice-President:* J. E. Settle; *Second Vice-President:* Edward Shroyer; *Director:* K. S. Watson; *Secretary-Treasurer:* R. G. McCall, State Dept. of Health, Room 643, State Capitol, Charleston 5, W. Va.

HONORARY MEMBERS

Bugbee, Julius W. (1942), 290 Massachusetts Ave., Providence, R. I.

Emerson, Charles A. (1941), Havens & Emerson, Woolworth Bldg., New York 7, N. Y.

Hyde, Charles Gilman (1943), Cons. Engr., 2599 Buena Vista Way, Berkeley 8, Calif.

Mohlman, Dr. Floyd W. (1944), Dir., Div. of Lab., Chicago San. Dist., 910 S. Michigan Ave., Chicago 5, Ill.

Moses, Howard E. (1943), Chief San. Engr., Pa. Dept. of Health, 1522 N. Second St., Harrisburg, Pa.

Orchard, William J. (1946), Gen. Mgr., Wallace & Tiernan Co., Newark, N. J.

Pearse, Langdon (1932), San. Engr., Chicago San. Dist., 910 S. Michigan Ave., Chicago 5, Ill.

Rudolfs, Dr. Willem (1945), Chmn., Dept. of Sanitation, Agricultural Experiment Station, Short Course Bldg., New Brunswick, N. J.

ASSOCIATE MEMBERS

Albert Pipe Supply Co., Inc., Berry & N. 13th St., Brooklyn 11, N. Y., Rep. J. J. Dougherty.

Aluminum Co. of America, 2100 Gulf Bldg., Pittsburgh, Pa., Rep. F. J. Close.

American Brass Co., Waterbury, Conn.

American Cast Iron Pipe Co., Birmingham, Ala., Rep. E L. Gilder.

American City Magazine, 470 Fourth Ave., New York, N. Y., Rep. Edgar J. Buttenheim, Pres. & Mgr.

American Concrete Pipe Assn., 228 N. LaSalle St., Suite 1033, Chicago 1, Ill., Rep. Howard F. Peckworth, Managing Dir.

American Well Works, Aurora, Ill., Rep. W. N Rensburg.

Armco Drainage Product Assn., Middletown, Ohio, Rep. W. H. Spindler, Publicity Mgr.

Automatic Control Co., 1005 University Ave., St. Paul 4, Minn., Rep. J. S. Williams.

Builders-Providence, Inc., Div. of Builders Iron Foundry, P. O. Box 1342, Providence, R. I., Rep. C. G. Richardson.

Cambridge Instrument Co., 3732 Grand Central Terminal, New York, N. Y., Rep. R. H. Kruse, Pres.

Carter Co., Ralph B., 192 Atlantic St., Hackensack, N. J., Rep. J. W. Van Atta.

Chain Belt Co., Milwaukee, Wis., Rep. W. B. Marshall, Sales Promotion Mgr.

Chapman Valve Mfg. Co., 203 Hampshire St., Indian Orchard, Mass.

Chicago Pump Co., 2300 Wolfram St., Chicago, Ill., Rep. Milton Spiegel, Vice-Pres. & Gen. Mgr.

Clay Products Assn., 111 W. Washington St., Chicago 2, Ill., Rep. J. D. Cook, Sec.

Climax Engineering Co., Chicago Office, 111 W. Monroe St., Rm. 922, Chicago 3, Ill., Rep. E. D. West, Mgr.

Crane Co., 836 S. Michigan Ave., Chicago 5, Ill., Rep. G. W. Hauck, Mgr., Eng. Sales Section.

DeLaval Steam Turbine Co., Trenton 2, N. J., Rep. H. V. Petersen, Sales Mgr.

Dickey Clay Mfg. Co., W. S., 607 Commerce Trust Bldg., Kansas City, Mo., Rep. A. G. Frerking, Vice-Pres. & Sales Mgr.

Dorr Co., Inc., 570 Lexington Ave., New York, N.Y.

Eastern Sewage Disposal Co., Inc., 930 F St., N.W., Atlantic Bldg., Rm. 605, Washington 4, D. C., Rep. Homer Trimble.

Eimco Corp., 3319 S. Wallace St., Chicago 16, Ill., Rep. Paul O. Richter, Mgr. Central Div.

Engineering News-Record, 330 W. 42nd St., New York, N. Y.

Everson Mfg. Co., 214 W. Huron St., Chicago 10, Ill., Rep. R. B. Everson, Pres.

Fairbanks, Morse & Co., 80 Broad St., New York 4, N. Y., Rep. Charles J. Prestler, Mgr. Pump Sales.

Flexible Sewer-Rod Equipment Co., 9059 Venice Blvd., Los Angeles, Calif., Rep. Peter L. Ciacco, Mgr.

Gale Oil Separator Co., Inc., 52 Vanderbilt Ave., New York, N. Y., Rep. William A. Gehle, Pres.

General Chemical Co., 3357 W. 47th Place, Chicago 32, Ill., Rep. L. I. Birdsall, Tech. Service Div.

General Electric Co., 1 River Rd., Schenectady, N. Y., Rep. H. V. Crawford.

Glamorgan Pipe & Foundry Co., Lynchburg, Va., Rep. John D. Capron.

Green Bay Fdy. & Machine Wks., 401 S. Broadway, Green Bay, Wis., Rep. James P. North, Pres.

Gruendler Crusher & Pulverizer Co., 2915 N. Market St., St. Louis, Mo., Rep. Willian P. Gruendler, Sec.-Treas.

Hardinge Co., York, Pa., Rep. M. C. Fleming.

Hershey Mfg. Co., Corner of E & Second Sts., South Boston 27, Mass., Rep. William C. Sherwood.

Homelite Corp., Port Chester, N. Y., Rep. Nelson Thompson.

Infilco, Inc., 325 W. 25th Place, Chicago, Ill., Rep. H. W. Gillard.

Iowa Valve Co., 201 N. Talman Ave., Chicago, Ill., Rep. J. W. Dousette, Gen. Sales Mgr.

Jeffrey Mfg. Co., Columbus, Ohio, Rep. S. L. Tolman.

Johns-Manville Corp., 22 E. 40th St., New York, N. Y., Rep. R. F. Orth, Mgr., Transite Pipe Dept.

Josam Mfg. Co., 1783 E. 11th St., Cleveland, Ohio, Rep. Leo N. Newman.

Lakeside Engineering Corp., 222 W. Adams St., Chicago, Ill., Rep. R. O. Friend.

Limestone Products Corp. of America, Newton, N. J., Rep. Peter J. Kelley, Service Rep.

Link-Belt Co., 2045 W. Hunting Park Ave., Philadelphia, Pa., Rep. William L. Hartley.

Ludlow Valve Mfg. Co., P. O. Drawer 388, Troy, N. Y., Rep. Robert Bischoff.

Lynchburg Foundry Co., Lynchburg, Va., Rep. W. Ray Odor.

Mathieson Alkali Works, Inc., 60 E. 42nd St., New York 17, N. Y., Rep. J. O. Logan.

Mine Safety Appliances Co., Braddock, Thomas & Meade Sts., Pittsburgh, Pa., Rep. N. R. Chillingworth, Sales Statistical Dept.

Mueller Co., 512 W. Cerro Gordo St., Decatur, Ill.

National Water Main Cleaning Co., 30 Church St., New York, N. Y., Rep. J. A. Frank, Pres. & Gen. Mgr.

Nichols Engineering & Research Corp., 60 Wall Tower, New York, N. Y., Rep. R. W. Rowen, Vice-Pres.

Omega Machine Co., 9 Codding St., Providence, R. I.

Pacific Flush Tank Co., 4241 Ravenswood Ave., Chicago, Ill., Rep. L. E. Rein, Pres.

Pennsylvania Salt Mfg. Co., 40 W. 40th St., New York 18, N. Y., Rep. B. P. Steele.

Pittsburgh-Des Moines Co., Neville Island Branch, Pittsburgh, Pa., Rep. J. E. O'Leary.

Pittsburgh Equitable Meter Co., 400 N. Lexington Ave., Pittsburgh, Pa., Rep. W. F. Weimer.

Pittsburgh Pipe Cleaner Co. of New York, 3004 Woolworth Bldg., New York 7, N. Y., Rep. Kyle I. Robinson, Pres.

Proportioneers, Inc., P. O. Box 1442, Providence, R. I., Rep. H. E. Hollberg, Vice-Pres.

Public Works Magazine, 310 E. 45th St., New York, N. Y.

Quigley Co., Inc., 527 Fifth Ave., New York 17, N. Y.

Royer Foundry & Machine Co., 158 Pringle St., Kingston, Pa., Rep. S. B. Davies, Pres. & Gen. Mgr.

Sewage Works Engineering, 24 W. 40th St., New York, N. Y., Rep. Karl M. Mann.

Sidu Co., Box 3537, Long Beach, Calif., Rep. M. O. Preen.

Simplex Valve & Meter Co., 68th & Upland Sts., Philadelphia, Pa., Rep. Everett M. Jones, Sales Mgr.

Smith Mfg. Co., A. P., 545 N. Arlington Ave., East Orange, N. J., Rep. W. P. Baerenrodt, Treas.

United Chromium, Inc, 2751 E. Jefferson Ave., Detroit 7, Mich., Rep. H. D. McLeese, Vice-Pres.

United States Pipe & Foundry Co., Burlington, N. J.

Vapor Recovery Systems Co., 30 Church St., New York, N. Y., Rep. C. T. Stanhope, Eastern Sales Mgr.

Wailes Dove-Hermiston Corp., Westfield, N. J., Rep. W. H. T. Thornhill, Vice-Pres.

Walker Process Equipment, Inc., 33 Hoyt Place, Aurora, Ill., Rep. J. D. Walker, Pres.

Wallace & Tiernan Co., Inc., 11 Mill St., Belleville, N. J., Rep. B. M. Lindsay.

Water & Sewage Works, 155 E. 44th St., New York, N. Y.

Werfelman Co., George H., P. O. Box 2590, Los Angeles 28, Calif., Rep. R. E. Garwood.

Wood Co., R. D., Public Ledger Bldg., Independence Sq., Philadelphia 5, Pa.

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Professional Opportunities

REGULAR CORPS APPOINTMENTS FOR ENGINEER OFFICERS IN THE U. S. PUBLIC HEALTH SERVICE

Competitive examinations for appointments in the Regular Corps in the U. S. Public Health Service in grades of Assistant Sanitary Engineer (1st Lieutenant) and Senior Assistant Sanitary Engineer (Captain) will be held during June, 1948. Approximately 15 appointments are to be made.

Salary

Entrance pay for the Assistant grade with dependents is $3,811 a year and for the Senior Assistant grade with dependents is $4,351 a year. Promotions are at regular intervals up to and including the grade of Senior Sanitary Engineer, which corresponds to the rank of Lieutenant Colonel, at $7,018 a year. Promotion to grades above Senior Sanitary Engineer is by selection. Retirement pay after 30 years service or at the age of sixty-four is $4,950 a year. Full medical care including disability retirement at three-fourths base pay and thirty days annual leave with pay are provided.

Qualifications

An applicant for the Assistant grade must (1) be a citizen of the United States at least 21 years of age, (2) have a degree in one of the several branches of engineering, from a school of recognized standing, and (3) have had at least 7 years of educational (exclusive of high school) and professional training or experience. At least 2 of the 7 years shall be qualifying professional training or experience in the field of public health or in an acceptable related field.

An applicant for the Senior Assistant grade must meet requirements (1) and (2) stated for the Assistant grade, and in addition have had 11 years of education (exclusive of high school) and professional training or experience. At least 6 of the 11 years shall be qualifying professional training or experience in the field of public health in the employment of an official or nonofficial health agency or in an activity directly related to the field of public health.

Examinations

Each applicant will receive a physical examination by a medical officer of the Public Health Service and a written examination, and will be rated by a Board of Officers as to professional knowledge and general fitness.

Apply

Application forms and additional information may be obtained from the Surgeon General, U. S. Public Health Service, Washington 25, D. C. Applications should be submitted without delay and must be received prior to June 1, 1948. The written examination is scheduled for June 21, 22, and 23, and will be held at designated Service Stations convenient to the candidates. Applicants will be notified regarding the date and location of the oral examinations. Transportation expenses to and from, and the cost of maintenance at, the place of examination must be assumed by the applicant. The written examination will require approximately 3 days.